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THE ELG TARGET SELECTION WITH THE BOSS SURVEY

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Abstract. The Baryon Acoustic Oscillation (BAO) feature in the power spectrum of galaxies can be used as a standard ruler to probe the accelerated expansion of the Universe. In this paper, we study several galaxy selection schemes aiming at building an emission-line galaxy (ELG) sample in the redshift range $0.6 < z < 1.7$, that would be suitable for future BAO studies using the Baryonic Oscillation Spectroscopic Survey (BOSS) spectrograph on the Sloan Digital Sky Survey (SDSS) telescope. We explore two different color selections using both the SDSS and the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS) photometry in the u, g, r, i bands and evaluate their performance for selecting bright ELG. This study confirms the feasibility of massive ELG surveys using the BOSS spectrographs on the SDSS telescope for a BAO detection at redshift $z \sim 1$, in particular for the proposed eBOSS experiment.

Keywords: BOSS, Emission Line Galaxies (ELG), target selection

1 Introduction

The evidence for the acceleration of the expansion of the Universe (Riess et al. 1998; Perlmutter et al. 1999) led to the existence of a new, enigmatic dark energy that opposes the self-attraction of matter. Even though the ΛCDM model, which consists of an inflationary cold dark matter model with a cosmological constant, is strongly favored, other interpretations have been suggested to explain cosmic acceleration. Alternatives involve scalar field models as quintessence, modification of the General Relativity itself on cosmological scales or extra dimensions of space-time. There is no doubt that understanding the nature of dark energy is one of the most important puzzles nowadays in cosmology.

Observational exploration is crucial to provide clues to the energy content of the Universe. One of the leading methods for measuring the expansion history is to use the Baryon Acoustic Oscillations feature (BAO) in the clustering of galaxies as a standard ruler (Seo & Eisenstein 2003). The BAO refer to the imprint of acoustic waves in the early Universe frozen after the decoupling of baryons and photons. Anticipated as a potential effect of the CMB as early as 1970s (Peebles & Yu 1970; Sunyaev & Zeldovich 1970), the first convincing BAO detections came in 2005 from the SDSS Data Release 3 (DR3) and the final 2dFGRS samples (Eisenstein et al. 2005; Cole et al. 2005). Recently, new BAO detections have been reported. Beutler et al. (2011) reported a 4.5% distance measurement at low redshift $z \sim 0.1$ with the 6dFGRS sample, and the acoustic scale has been measured in the redshift range $0.16 < z < 0.47$ by the final SDSS-II sample (DR7) with a distance precision of 2.7% (Percival et al. 2010; Kazin et al. 2010). Steping beyond $z = 0.5$, BAO feature has been measured in the SDSS-III Baryon Oscillation Spectroscopic Survey (BOSS;(Dawson et al. 2012)) (DR9) with a sample of higher redshift luminous red galaxies (LRG) in the redshift range $0.43 < z < 0.7$ (Anderson et al. 2012). Adding to these data, the WiggleZ Dark Energy Survey has quantified BAO by targeting bright emission-line galaxies (ELG) in the range $0.3 < z < 0.9$ (Blake et al. 2011).

In summary, the BAO peak has been detected in several galaxy samples to $z < 1$, and there are strong motivations for extending these large-scale structure measurements to higher redshifts. The BAO method measures the cosmic distance in both radial and transverse directions, giving the Hubble parameter $H(z)$ and the angular diameter distance $D_A(z)$, respectively. Beyond the BAO, the full shape of the galaxy power spectrum

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provides useful information to constrain cosmological parameters and even to test deviations from Einstein's theory of gravity (White et al. 2009). Thought to be the cosmological probe the least affected by systematic uncertainties according to the Dark Energy Task Force (DETF;(Albrecht et al. 2006)), the BAO probe requires to map very large cosmic volumes to achieve a precise distance measurement (as baryons comprise only a small fraction of matter, the amplitude of the BAO peak is small). In addition, resolving the features of BAO along the line-of-sight motivates the need for spectroscopic redshift surveys. The next generation of cosmological surveys (the stage IV facilities as defined in the DETF report) plans to map the high redshift Universe in the range $0.6 < z < 2$. On the ground, BigBOSS would carry out spectroscopic surveys of 10 million galaxies by targeting LRG to $z = 1$ and ELG to $z = 1.7$ (Schlegel et al. 2011). In space, the ESA's Euclid mission plans to measure redshifts of 50 million strong Hα emitters in the redshift range $0.7 < z < 2$ (Laureijs et al. 2011).

Motivated by future BAO surveys as eBOSS[i] or BigBOSS, this paper deals with a galaxy target selection to identify ELG in the redshift range $0.6 < z < 1.7$. Section 2 describes the color selection using imaging data from the Sloan Digital Sky Survey (SDSS) and the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS). In section 3 we describe the simulation of ELG spectra using the Cosmos Mock Catalog as well as the expected redshift success rate when spectra are observed with the BOSS spectrograph. Section 4 concludes with the visual inspection of $2,000$ spectra observed during an ancillary program of BOSS dedicated to this study.

2 The ELG color selection

At lower redshift, luminous red galaxies are good candidates for spectroscopic surveys as they have strong absorption features like the 4000 break. However, from $z > 1$, the 4000 break moves into the infrared and, as red galaxies become very faint, long exposure time is required. Moreover density of LRG targets falls dramatically at $z > 1$ as shown in Fig. 1. At high redshift near $z \sim 3$, a challenging option is to target quasars (QSOs). By instance, one of the key goals of the BOSS project is to study BAO features using Lyman-α forest absorption spectra of distant quasars in the range $2.2 < z < 3.5$ (McDonald & Eisenstein 2007; Ross et al. 2012). When working at $z \sim 1$, a relevant choice is emission-line galaxies, including both strongly star-forming galaxies and emission-line QSOs. In this paper, we only consider star-forming emission-line galaxies that we call ELG. One of the advantages of ELG is that emission lines can be detected even when the continuum is weak. The redshift extraction is based on identification of emission lines, with the detection of the [OII] λ3727 doublet for $0.6 < z < 1.6$.

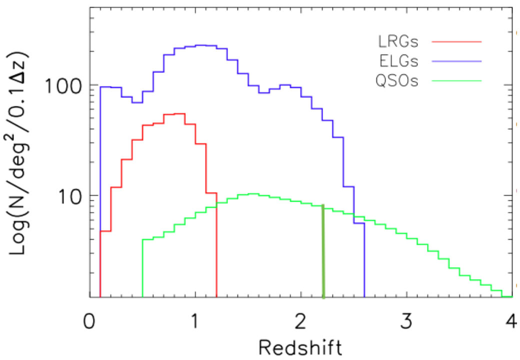

Fig. 1. Density of luminous red galaxies (LRG), emission-line galaxies (ELG) and quasars (QSO) as a function of redshift.

The aim of this work is to apply selection criteria to BOSS that uses the 2.5-m SDSS telescope at Apache Point Observatory (Gunn et al. 2006). The SDSS photometric survey, delivered under the data release 8 (DR8, (Aihara et al. 2011)), covers $14,555$ square degrees in the 5 photometric bands u, g, r, i, z. The 3σ magnitude depths are: $u = 22.0$, $g = 22.2$, $r = 22.2$, $i = 21.3$. The magnitudes we use are corrected from galactic extinction. In addition, we use the CFHTLS photometric redshift catalog (Ilbert et al. 2006; Coupon et al. 2009). The CFHTLS covers 155 square degrees in the u, g, r, i, z bands, with transmission curves of filters slightly different from SDSS. The 3σ magnitude depths are: $u = 25.3$, $g = 25.5$, $r = 24.8$, $i = 24.5$, thus the CFHTLS photometry

[i]extendedBOSS is part of a proposed program of post-2014 surveys on the Sloan telescope.

is much deeper than SDSS DR8, however the CFHTLS covers only a small fraction of the SDSS field of view. The photometric redshift accuracy is estimated to be $\sigma_z < 0.04\,(1+z)$ for $g < 22.5$.

In this paper we explore two color selections based on *ugr* and *gri* color-color diagrams.

The *ugr* color selection is defined by $-1 < u-r < 0.5$ and $-1 < g-r < 0.5$ that selects strongly star-forming galaxies at $z > 0.6$. An additional cut $-1 < u-g < 0.5$ removes all low-redshift galaxies ($z < 0.3$). For this selection, the bright sample is defined for the g magnitude between $20 < g < 22.5$ and the faint sample for $g < 23.5$ (Fig. 2 Left). The *ugr* color selection avoids the stellar sequence, but not the quasar sequence. Hence, the contamination of the *ugr* selection by point-source objects is expected to be due to quasars. The selection is centered to $z \sim 1.3$.

The bright sample of the *gri* color selection is defined by the magnitude cut $19 < i < 21.3$, where in addition blue galaxies at $z \sim 0.8$ are selected with $0.8 < r-i < 1.4$ and $-0.2 < g-r < 1.1$ (Fig. 2 Right). In the faint range defined as $21.3 < i < 23$, we tilt the selection to select higher redshifts with $-0.4 < g-r < 0.4$, $-0.2 < r-i < 1.2$ and $g-r < r-i$. The *gri* selection avoids both the stellar sequence and the quasar sequence. Thus the contamination from point-sources should be minimal. The selection is centered to $z \sim 0.8$ (bright) and $z \sim 1$ (faint).

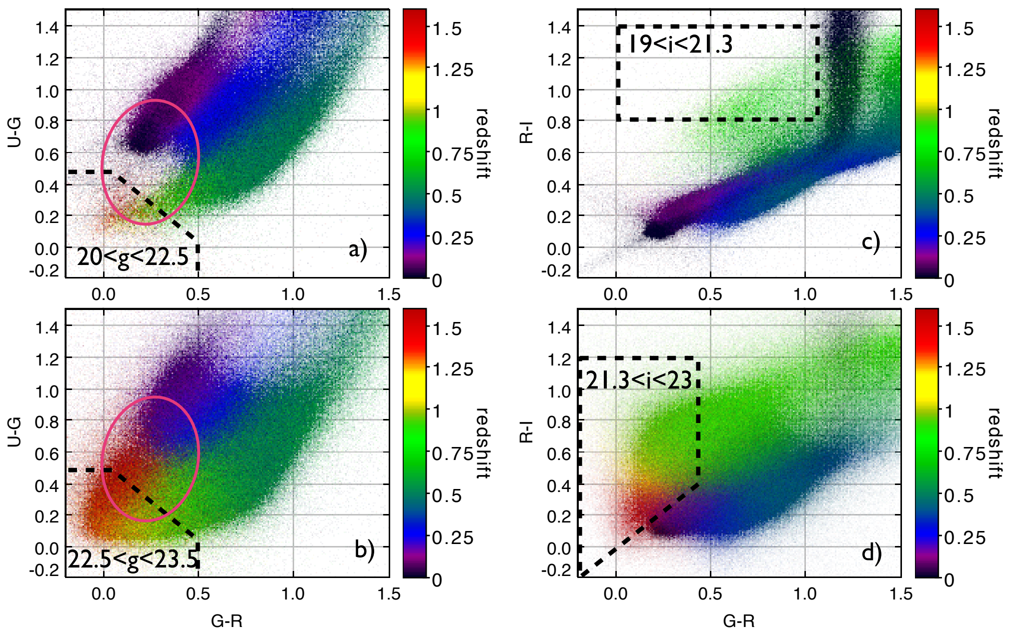

Fig. 2. Color-color diagrams in the CFHTLS photometric database. **Left:** The *ugr* selection for the bright (top) and the faint (bottom) samples. **Right:** The *gri* selection for the bright (top) and the faint (bottom) samples.

3 Validation using simulations

In order to be able to evaluate the color selection efficiency, we need for a spectro-photometric catalog with a large sample of galaxy spectra. In this aim, we use the COSMOS Mock Catalog (CMC) based on the COSMOS photometric catalog (Ilbert et al. 2009). The CMC contains about 280,000 galaxies, in which each simulated galaxy has a photo-z and a best-fit template (Jouvel et al. 2009). In addition, with each galaxy of the CMC is associated a simulated spectrum, for which emission lines have been added using Kennicutt calibration laws (Kennicutt 1998; Ilbert et al. 2009) and calibrated using zCOSMOS (Lilly et al. 2009) as described in (Zoubian et al. 2012). The strength of [OII] emission lines was confirmed using DEEP2 and VVDS DEEP luminosity functions (Le Fèvre et al. 2005; Zhu et al. 2009). Finally a host galaxy extinction law is applied to each spectrum. From the CMC, two simulated galaxy catalogs were built, one for each color selection function (*ugr* and *gri*), for $0.6 < z < 1.7$. Each synthetic spectrum was affected by sky and photon noise as if observed by the BOSS spectrographs (Smee et al. 2012), by using the *specsim1d* software. We simulated a set of four exposures of 900 seconds each.

To extract the spectroscopic redshift, the resulting simulated spectra were then analyzed by the two redshift codes of the BOSS pipeline software, the idlspec2d software (Bolton et al. 2012) and a modified version of the Zcode Fortran program, initially developed by (Sutherland 1999) and made available to the BOSS community. While the former, primarily designed for LRG targets, is based on a least-squares minimization using galaxies templates, the latter performed also a redshift estimate based on fitting discrete emission line templates in Fourier space over all z. In a further step we address the flux measurement of emission lines, conducted using the Platefit Vimos software developed by (Lamareille et al. 2009). This software was developed to measure the flux of all emission lines after removing the stellar continuum and absorption lines from lower resolution and lower signal-to-noise ratio spectra (Lamareille et al. 2006).

Finally we define a successful redshift measurement if $\delta z/(1+z) < 0.004$. The redshift success rate (RSR) of the *ugr* selection is shown in Fig. 3 for the two redshift codes of the BOSS pipeline, using galaxies templates (in red) and emission lines templates (in blue). The redshift extraction is not meaningful below $z < 0.6$ due to the lack of statistics. The RSR is higher than 70% for $z < 1.5$, and is about 90% for the n(z) distribution between $0.6 < z < 1.6$. For $z > 1.6$, the redshift extraction always fails, and some catastrophic failures ($\delta z/(1+z) > 0.01$) remain for $1 < z < 1.6$, essentially due to the bad identification of the [OII] emission line view as the $H\alpha$ line.

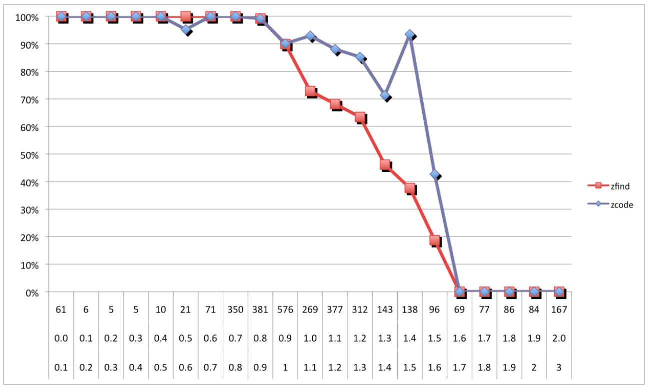

Fig. 3. Redshift success rate of the *urg* sample with the two redshift codes of the BOSS pipeline.

4 Validation using ancillary observations

To test the reliability of both the bright *ugr* and *gri* color selections, we have conducted a set of dedicated observations, as part of the Emission Line Galaxy SDSS-III/BOSS ancillary program. The observations were conducted between Autumn 2010 and Spring 2011 using the SDSS telescope with the BOSS spectrograph. A total of $\sim 2,000$ spectra, observed four times of 15 minutes, were taken in different fields: in the Stripe 82 (using single epoch SDSS photometry for color selection) and in the CFHTLS W1, W3 and W4 wide fields (using CFHT-LS photometry). This data set has been released in the SDSS-III DR9 (Ahn et al. 2012).

All these observed spectra were visually inspected to confirm or correct the redshifts produced by two different pipelines. To classify the observed objects, we have defined sub-categories, one with secure redshifts and the other with unreliable redshifts. For the targets selected using the SDSS photometry and the *ugr* color selection : 32% are ELGs at z > 0.6, and 32% are ELGs at $z < 0.6$. Besides, 20% are flagged as bad data, and QSOs are 10% of the selected targets. Within the *gri* selection, 50% of targets are ELGs at $z > 0.6$.

Using the CFHTLS photometry, 46% of targets are ELGs at z > 0.6 and 14% are QSOs with the *ugr* selection. Within the *gri* selection, 61% are ELGs at $z > 0.6$, 12% are red galaxies with a strong continuum, and only 1% of targets are QSOs. For both bright and faint samples, 18% of spectra are bad data (for a complete description, see Comparat et al. (2012).

5 Conclusions

We present an efficient emission-line galaxy selection that could provide a sample from which the BAO feature could be measured in the 2-point correlation function at $z > 0.6$. Using such deeper photometric surveys and improved pipelines, it should be possible to probe BAO to $z = 1.2$ in the next 6 years, e.g. by the eBOSS experiment, and to $z = 1.7$ in the next 10 years, e.g. by PFS-SuMIRE or BigBOSS experiment.

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