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Preliminary Target Selection for the DESI Luminous Red Galaxy (LRG) Sample

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ABSTRACT

The DESI survey will observe more than 8 million candidate luminous red galaxies (LRGs) in the redshift range $0.3 < z < 1.0$. Here we present a preliminary version of the DESI LRG target selection developed using Legacy Surveys Data Release 8 g, r, z and $W1$ photometry. This selection yields a sample with a uniform surface density of ~ 600 deg^{-2} and very low predicted stellar contamination and redshift failure rates. During DESI Survey Validation, updated versions of this selection will be tested and optimized.

Keywords: surveys, large-scale structure, cosmology: observations

INTRODUCTION

The Dark Energy Spectroscopic Instrument (DESI, DESI Collaboration et al. 2016) will be used to obtain spectra of more than 8 million luminous red galaxies (LRGs) in the redshift range $0.3 < z < 1.0$, in addition to samples of stars, quasars and other galaxies. LRGs are massive galaxies that have typically ceased star formation and which occupy highly biased structures. Their spectra have a strong 4000 Å break, which makes their redshifts relatively easy to measure. These properties make LRGs an ideal tracer for mapping the large-scale structure of the Universe. Here, we describe a preliminary DESI LRG selection designed using Data Release 8 (DR8) of the DESI Legacy Imaging Surveys (Dey et al. 2019)[1], and make the resulting target catalogs public[2].

[1] http://legacysurvey.org/dr8/
[2] Available at https://data.desi.lbl.gov/public/ets/target/catalogs/ and detailed at https://desidatamodel.readthedocs.io

LRG TARGET SELECTION

Our LRG targets are selected using Legacy Surveys (LS) DECaLS/BASS/MzLS g, r, z, and *WISE* (Wright et al. 2010) $W1$ photometry (Dey et al. 2019). The targets are much brighter than the limits of the imaging data. As a result the selection is insensitive to variations in imaging properties such as depth, yielding a uniform surface density across the survey footprint.

For lower-redshift LRGs, it is possible to select objects with red optical colors exploiting the 4000 Å break, as done for SDSS-I (Eisenstein et al. 2001) and BOSS (Reid et al. 2016), but such methods fail when the break moves beyond the r band. For the eBOSS survey (Dawson et al. 2016), WISE photometry was used to reject stars and efficiently select massive galaxies at higher redshift (see Prakash et al. 2015, 2016). This method takes advantage of the prominent $1.6\,\mu$m (restframe) "bump" (John 1988; Sawicki 2002) which produces an excess of flux in the $W1$ ($3.4\,\mu$m) band for $z \sim 1$ galaxies.

The color and magnitude cuts used to select LRGs in the DECaLS (Southern) DR8 imaging are:

$$(z - W1) > 0.8 \times (r - z) - 0.6, \tag{1a}$$

$$((g - W1 > 2.6) \text{ AND } (g - r > 1.4)) \text{ OR } (r - W1 > 1.8), \tag{1b}$$

$$(r - z > (z - 16.83) \times 0.45) \text{ AND } (r - z > (z - 13.80) \times 0.19), \tag{1c}$$

$$r - z > 0.7, \tag{1d}$$

$$\text{and } z_{\text{fiber}} < 21.5, \tag{1e}$$

where g, r, z, and $W1$ indicate the extinction-corrected AB magnitudes in the corresponding band (using LS extinction corrections[3]), and z_{fiber} is the magnitude corresponding to the expected z flux within a DESI fiber. Tweaks are needed to select an equivalent sample in the Northern (BASS/MzLS) DR8 imaging due to differences in instruments and passbands; the cuts which differ are:

$$(z - W1) > 0.8 \times (r - z) - 0.65, \tag{2a}$$

$$((g - W1 > 2.67) \text{ AND } (g - r > 1.45)) \text{ OR } (r - W1 > 1.85), \tag{2b}$$

$$\text{and } (r - z > (z - 16.69) \times 0.45) \text{ AND } (r - z > (z - 13.68) \times 0.19). \tag{2c}$$

We require all targets to be covered by at least one image in each optical band. We remove saturated objects and sources near bright stars, large galaxies, or globular clusters by requiring that LS `MASKBITS`[4] 1, 5, 6, 7, 11, 12, and 13 are not set.

The boundaries in color-magnitude space corresponding to Equations 1a-e and the predicted redshift distribution for the sample are depicted in Figure 1. The first cut (shown in the upper left panel of Figure 1) provides an effective rejection of stars, much as in Prakash et al. (2016). The cuts shown in the upper-right panel eliminate low-redshift or bluer objects. As shown in the lower-left panel, applying a magnitude limit which is a function of color allows only the most luminous objects at a given redshift to be selected. In addition to these cuts, we also apply a limit on z_{fiber} to ensure targets yield secure redshift measurements.

We have also developed alternative approaches which apply a single, broader $r - W1$ cut independent of $g - r$, and which employ a magnitude limit in the $r - W1$ vs. $W1$ plane instead of in z. The resulting selection eliminates g and reduces z-band dependence (making it less sensitive to photometric calibration errors) but still yields a similar redshift distribution to that shown in Figure 1.

CONCLUSIONS

LRG targets selected as outlined in this Note have a total surface density of ~ 600 deg^{-2} and a roughly constant comoving density of $\sim 6 \times 10^{-4}\, h^3\, \text{Mpc}^{-3}$ over the redshift range $0.3 < z < 0.8$. Tests with DESI commissioning data suggest that in nominal conditions $> 98\%$ of these targets should yield secure redshift measurements, with $< 1\%$ stellar contamination at high Galactic latitudes. Legacy Surveys DR9 imaging and DESI Survey Validation (SV) spectroscopy will soon be used to choose the best method for LRG targeting and optimize the selection cuts for the DESI survey. We expect the DESI LRG sample to meet or exceed all relevant Science Requirements[5] and to surpass previous spectroscopic LRG surveys in areal coverage, redshift range, and overall number of targets.

[3] http://www.legacysurvey.org/dr8/catalogs/#galactic-extinction-coefficients

[4] http://www.legacysurvey.org/dr8/bitmasks/

[5] https://cmb-s4.org/wiki/images/DESI_L123_driver.pdf

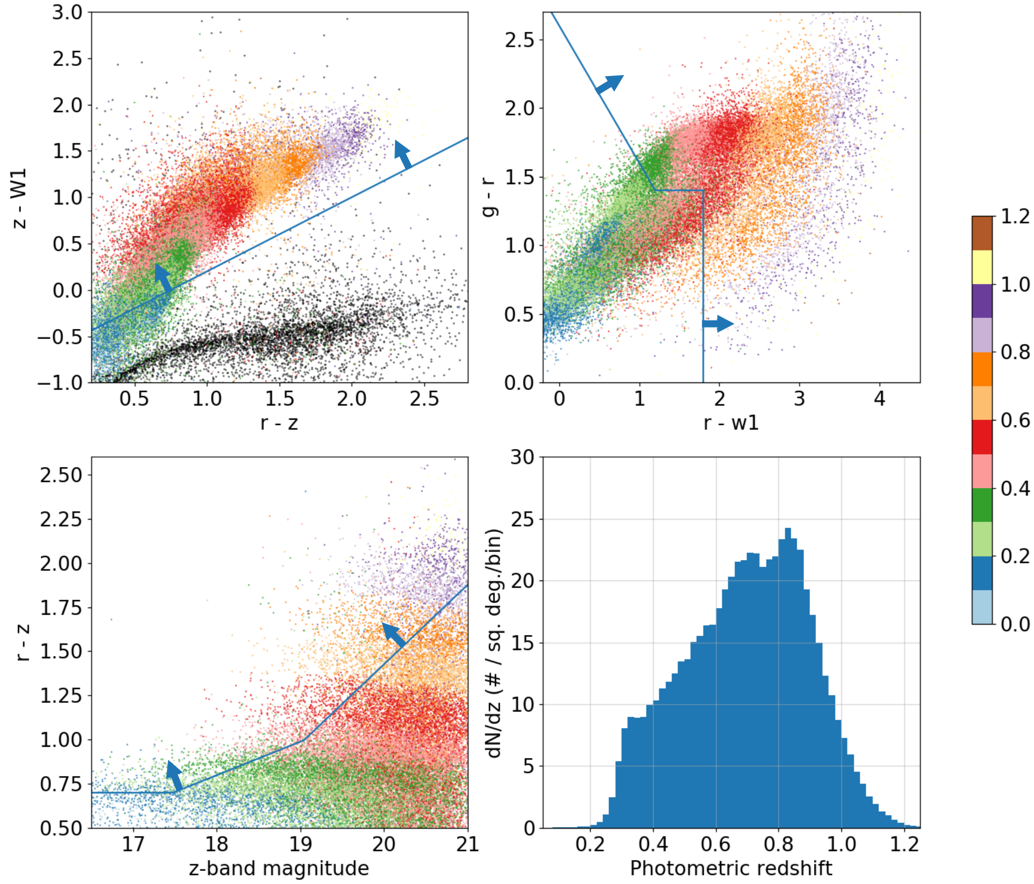

Figure 1. Illustration of the selection cuts for the DESI LRG sample, as listed in Equation 1. The first three panels present optical/near-infrared color-color and color-magnitude diagrams for objects from LS DR8. All extended sources with z-band fiber magnitude brighter than 21.5 are color-coded according to their PRLS photometric redshifts (Zhou et al. 2020). Blue lines depict the LRG selection boundaries given in Equation 1. In the upper left panel, we also plot the color-color distribution of point sources (mostly stars) in black. The lower right panel shows the photometric redshift distribution for the selected targets, showing the number of LRGs per deg^2 in each $\Delta z = 0.02$ redshift bin.

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