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Discovery Spectroscopy for Unusual Point Sources

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Abstract

We propose a DESI spare-fiber secondary target program to obtain spectroscopy of all point sources of unusual color. Many of these sources will already be specifically targeted as quasars or as astrophysically interesting stars – Blue Horizontal Branch stars in the Milky Way halo, white dwarfs, brown dwarfs, etc. However, those target lists will only be looking for known classes of objects. This proposal would select those unusual sources missing from those lists, and therefore has the potential to both find missing quasars and to be a discovery engine for new, interesting objects.

1. SCIENCE JUSTIFICATION

Although DESI was primarily constructed to undertake a cosmological survey, its field of view, multiplex advantage, and spectral resolution make it an incredible instrument for discovery and exploration. Both astrophysics and cosmology are driven by discovery: rare astrophysical sources can enable the study of unusual and new physical phenomena, uncover new methods or probes of the universe, and provide unique laboratories for physics.

We propose to simply target any sources of type PSF that are inconsistent with the colors of main sequence stars and that are missed by other selection criteria. The main sequence of stars from F-type through M-type track a color locus with an intrinsic color dispersion of only a few per cent. Figure 1 shows the point sources in a 4 square degree patch of sky with an empirical fit to this locus indicated by the green line. Sources indicated as red points are "targets of interest". This clearly includes white dwarf stars (the bluest stars in the lower left), quasars (generally below the stellar locus), and some compact galaxies (above the stellar locus).

This is not a new idea. Catalogs of point sources of unusual color have been published previously, such as from the work of Covey et al. 2007 (`https://arxiv.org/abs/0707.4473`). However, this selection from the DESI imaging probes significantly deeper than the SDSS imaging, and this proposal finally gives the opportunity to spectroscopically observe a large number of these unusual objects.

This proposal will also benefit the DESI Key Project by identifying any missed populations of galaxies or quasars. For example, galaxies that have been missed because of their classification as TYPE=PSF will be picked up. And brighter quasars missed by the key projection selection algorithms will be picked up.

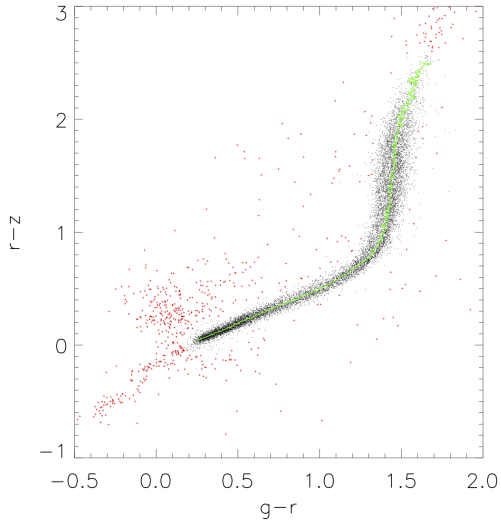

Figure 1. Color-color diagram for sources of TYPE=PSF brighter than $g \leq 22$ or $r \leq 22$ or $z \leq 22$ from the LS DR8 catalogs. Sources with colors that are more than 10-sigma from the main sequence are indicated as red points.

2. TARGET SELECTION

The resulting target density is 130 deg^{-2}, for a total of approximately 2 million over the full DESI footprint. Many of these may already be targeted as Milky Way targets during bright time, and as quasar targets during dark time. We

Mag range	Number/deg^2	Existing BRIGHT	Existing DARK
15–16	0.25	0	0
16–17	2	2	0.5
17–18	4	4	2
18–19	12	12	7
19–20	29	4	16
20–21	53	0	35
21–22	32	0	26
Total	132.25	22	86.5

Table 1. Number of targets per square degree as a function of r-band magnitude range, with the overlap in existing BRIGHT-time and DARK-time targets indicated in the 3rd and 4th columns.

propose to include the 18 deg^{-2} at $15 < r < 19$ as bright time spare fibers, and the 130 deg^{-2} at $16 < r < 22$ as dark time spare fibers. Approximately two-thirds of these targets are already in the "bright" or "dark" targeting catalogs, as indicated in the corresponding columns in Table 1. (These numbers are based upon the dr8/0.42.0 target catalogs.) We visually inspected several hundred of our targets, and virtually none of these appeared to be artifacts (see Figure 2 for some representative examples). We request a single observation per target. The sources are selected only from DESI imaging, so OVERRIDE=False. Because this is a discovery proposal on individual sources, the incompleteness and inhomogeneity of the targeting only acts to limit the discovery space.

During SV we will assess the resulting spectra to assess the outlier-selection criteria and the split between bright time and dark time. Since this is a discovery oriented project, we will use the "spare fiber" mode of observing. All our targets will be selected from LS DR9, and hence we will use OVERRIDE=False.

Figure 2. A subset of our point source color outliers in the COSMOS region and absent from existing DESI DR8 target lists. Each cutout is centered on a PSF color outlier target. Top: deep blue, pink, green, dark red. Bottom: orange, yellow, dark red, bright blue. These color composite renderings are built from Legacy Surveys DR8 grz optical imaging.