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Permalink
https://escholarship.org/uc/item/3np7x2zx

Journal
Research Notes of the AAS, 4(10)

ISSN
2515-5172

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Publication Date
2020-10-23

DOI
10.3847/2515-5172/abc1dc

Peer reviewed
Preliminary Target Selection for the DESI Milky Way Survey (MWS)

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ABSTRACT

The DESI Milky Way Survey (MWS) will observe ≥8 million stars between 16 < r < 19 mag, supplemented by observations of brighter targets under poor observing conditions. The survey will permit an accurate determination of stellar kinematics and population gradients; characterize diffuse substructure in the thick disk and stellar halo; enable the discovery of extremely metal-poor stars and other rare stellar types; and improve constraints on the Galaxy’s 3D dark matter distribution from halo star kinematics. MWS will also enable a detailed characterization of the stellar populations within 100 pc of the Sun, including a complete census of white dwarfs. The target catalog from the preliminary selection described here is publica)

a) Available at https://data.desi.lbl.gov/public/ets/target/catalogs/ and detailed at https://desidatamodel.readthedocs.io
Although DESI is conceived primarily as a cosmological experiment, in bright time the survey will obtain spectra of Milky Way stars within the DESI footprint selected from the *Gaia* DR2 catalog (Gaia Collaboration et al. 2018) and the DESI Legacy Imaging Surveys (LS; Dey et al. 2019). This Milky Way Survey (MWS) at Galactic latitudes $|b| > 22^\circ$ will share the DESI focal plane with the Bright Galaxy Survey (BGS; Ruiz-Macias et al. 2020), using approximately half of the DESI fibers available during bright time. In addition, bright stars across the entire sky (including Galactic plane sources) will be observed in twilight and poor weather conditions.

The MWS target selection is designed to be simple, inclusive, and amenable to forward modeling. It will yield an essentially magnitude-limited random sample of stars over a significant fraction of the sky that can be compared to theoretical predictions, a philosophy similar to that of the SDSS main galaxy sample. Comprised of ~8 million sources with *Gaia* parallaxes and proper motions but fainter than the $G = 16$ limit of *Gaia's* radial velocity spectrograph, MWS will more completely sample stellar kinematics far from the Galactic center.

**MWS Main Sample**

The MWS Main sample will target all stars (i.e., sources of type “PSF” from LS with *Gaia* DR2 astrometric-excess-noise $< 3$ mas) in the range $16 < r < 19$ mag, where $r$ is the LS apparent $r$-band magnitude corrected for Galactic extinction. A small number of stars with uncorrected magnitude $r_{\text{obs}} < 20$ will be excluded to ensure spectra of sufficient signal-to-noise (the DESI bright-time survey footprint is mostly at high latitude, hence low extinction). Stars will be assigned to one of the following three target classes based on their color and *Gaia* DR2 astrometry (Fig. 1).

- **MWS Main Blue**: all stars with $g - r < 0.7$ mag.
- **MWS Main Red**: stars with $g - r \geq 0.7$ mag; good parallaxes (*Gaia* astrometric_params_solved = 31, parallax $\pi < \max(3\sigma_\pi, 1)$ mas); and very small proper motion ($|\mu| < 7$ mas/yr).
- **MWS Main Broad**: stars with $g - r \geq 0.7$ not included in MWS Main Red.

For $g - r < 0.7$, the selection is a magnitude-limited random sampling, valuable for high-resolution kinematic studies of the thick disc and nearby halo using turn-off stars. For $g - r \geq 0.7$, the Main Red astrometric criteria exclude a significant fraction of nearby dwarfs and hence increase the probability of targeting more distant halo giants, useful for studies of kinematic and stellar population gradients to $\sim 100$ kpc. The Main Blue and Main Red selections are weighted equally in fiber assignment. The remaining stars are included in the Main Broad sample and assigned fibers at lower priority. The completeness and purity of the Main Red sample will be evaluated during the DESI Survey Validation (SV) phase (a precursor to the DESI ‘main’ science survey). The magnitude, color, proper motion, and parallax limits will be adjusted, if necessary, before the survey commences. We will prioritize all known *Gaia* RR Lyrae with $14 < G < 19$ (Clementini et al. 2019), and evaluate a blue horizontal branch (BHB) star selection based on *Gaia* and LS in this range.

**The Backup Survey**

During poor weather and twilight conditions, when the MWS Main and BGS observations are not possible, DESI will observe an “unbiased” bright star sample ($10.5 < G < 16$ mag) at declination $\delta \geq -30^\circ$. This Backup Survey is expected to yield spectroscopic parameters, abundances, and kinematics for several million stars, creating a rich resource for studies of disk stellar populations, stellar evolution, and Galactic structure.

**Sparse high-value targets**

MWS will also include sparse (< 10 deg$^{-2}$) samples of high-value targets. These will be given higher priority for fiber assignment but will not perturb the main sample selection function significantly.

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**White Dwarfs**—White dwarf (WD) stars can constrain the local star formation history, the nature of SN Ia progenitors, and the composition of exo-planetesimals. Selected following Gentile Fusillo et al. (2019), their priority will be the highest of all bright-time targets.

**Stars within 100 pc**—Gaia is complete for stars within 100 pc, and DESI will provide a comprehensive stellar population census of the solar neighborhood. This will establish strong constraints on the initial mass function and local chemical evolution. Target selection: $16 \leq G \leq 20$, $\pi + \sigma_\pi \geq 10$ mas. Stars with $G < 16$ are in the Backup Survey.

MWS may include these additional high-value targets:

**Distant halo tracers**—RR Lyrae, BHB and giant stars are excellent tracers of halo structure because reliable distances can be determined for them. We will target faint ($G > 19$) Gaia RR Lyrae and color-selected BHBs, and use DDO51 photometry over 10,000 deg$^2$ (Slater et al. 2016) to select a sparse sample of giants.

**Close white dwarf binaries**—Understanding the evolution of WD binaries, which include SN Ia progenitors and low-frequency gravitational wave sources, requires robust observational constraints (Toloza et al. 2019). These targets will be selected using Gaia/GALEX data as follows: $\pi/\sigma_\pi > 5$, $16 \leq G \leq 20$, $FUV + 5 \log 10(\pi''/\) + 5 > 1.5 + 1.28 \times (FUV - G)$.

**Cluster members**—We will use proper motion to select likely members of a few bright dwarf galaxies and globular clusters out to $\sim 10$ times their half-light radius. DESI is ideal for surveying the environs of such objects for signs of tidal interactions and extended halos.

**ACKNOWLEDGMENTS**

APC is supported by the Taiwan Ministry of Education Yushan Fellowship and MOST grant 109-2112-M-007-011-MY3. SK was partially supported by NSF grants AST-1813881, AST-1909584. TSL is supported by NASA through Hubble Fellowship grant HST-HF2-51439.001. MYW acknowledges the support of the McWilliams Postdoctoral Fellowship. MV is supported by NASA-ATP awards NNX15AK79G and 80NSSC20K0509 and the Michigan Institute for Computational Discovery and Engineering (MICDE).

This research is supported by the Director, Office of Science, Office of High Energy Physics of the DOE under Contract No. DE–AC02–05CH1123, and by NERSC, a DOE Office of Science User Facility under the same contract;
additional support for DESI is provided by NSF, Division of Astronomical Sciences under Contract No. AST-0950945 to the NSF’s NOIRLab; the UK STFC; the Gordon and Betty Moore Foundation; the Heising-Simons Foundation; the French Alternative Energies and Atomic Energy Commission (CEA); the National Council of Science and Technology of Mexico; the Ministry of Economy of Spain, and by the DESI Member Institutions. The authors are honored to be permitted to conduct astronomical research on Iolkam Du’ag (Kitt Peak), a mountain with particular significance to the Tohono O’odham Nation.

REFERENCES

Clementini, G., Ripepi, V., Molinaro, R., et al. 2019, A&A, 622, A60, doi: 10.1051/0004-6361/201833374

Dey, A., Schlegel, D. J., Lang, D., et al. 2019, AJ, 157, 168, doi: 10.3847/1538-3881/ab089d

Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al. 2018, A&A, 616, A1, doi: 10.1051/0004-6361/201833051

Gentile Fusillo, N. P., Tremblay, P.-E., Gänsecke, B. T., et al. 2019, MNRAS, 482, 4570, doi: 10.1093/mnras/sty3016

Slater, C. T., Nidever, D. L., Munn, J. A., Bell, E. F., & Majewski, S. R. 2016, ApJ, 832, 206, doi: 10.3847/0004-637X/832/2/206

Toloza, O., Breedt, E., De Martino, D., et al. 2019, BAAS, 51, 168. https://arxiv.org/abs/1903.04612