Discovery and Characterization of a New Ultra-Faint Stellar System with the DELVE Survey

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Introduction

Under the concordance ΛCDM cosmological model, galaxies exist within a hierarchical paradigm, with large, luminous galaxies inhabiting massive dark matter halos and fainter dwarf galaxies forming in substructure around these halos. This paradigm is expected to be fully self similar: the most massive dark matter subhalos, too, are predicted to host their own substructure.

The Large and Small Magellanic Clouds - the Milky Way's largest and most massive satellites - provide an excellent testing ground for these hierarchical models. Recent large-scale sky surveys - in particular, the Dark Energy Survey - have revealed a >3σ anisotropy in the distribution of dwarf galaxy satellites due to the influence of Magellanic Clouds; however, deep observational censuses of the region of sky near the Clouds remain incomplete.

The DECam Local Volume Exploration Survey (DELVE) is conducting a comprehensive census of the MW/LMC/SMC satellite population by combining archival community exposures and 126 nights of new observations to complete deep, wide-area coverage of the entire high-Galactic-latitude southern sky on the Dark Energy Camera.

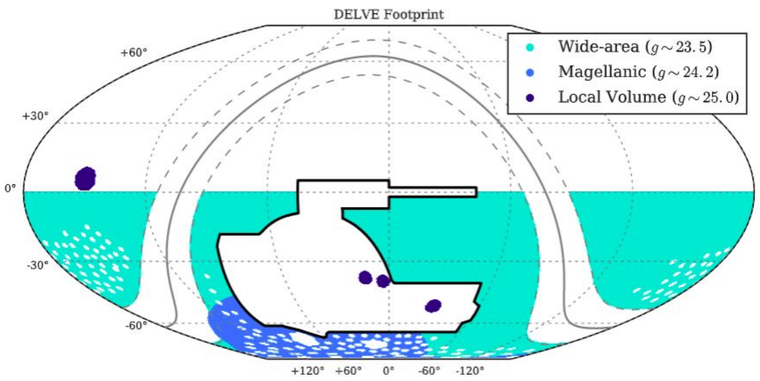
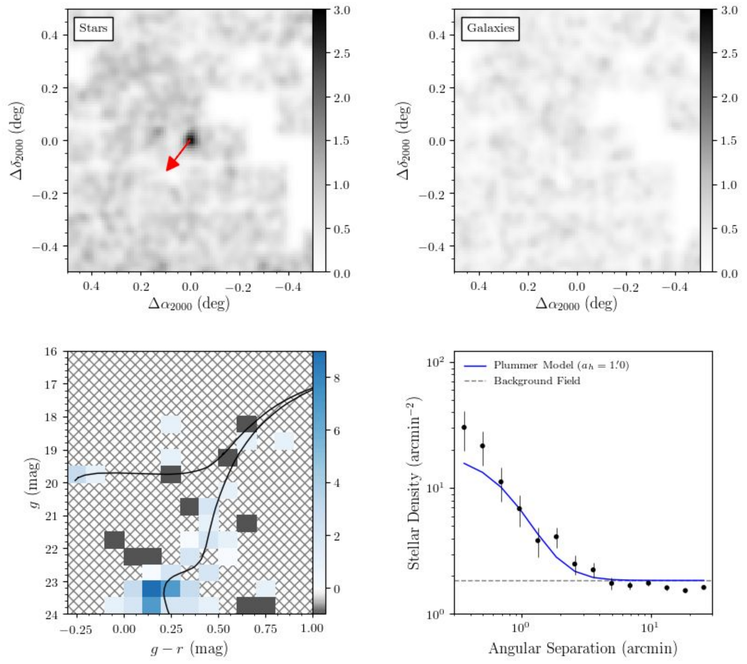


Figure: Skymap of planned DELVE coverage for all three survey components. Previous searches over the Wide-area footprint resulted in the discovery of the Centaurus I dwarf galaxy and the DELVE I Milky Way halo star cluster.

Search and Discovery

To detect new satellite systems, we scan for spatial overdensities of stars with fluxes and colors consistent with an old, metal poor stellar population using the **simple** search algorithm.

We begin by partitioning the Magellanic search region into equal-area HEALPix pixels. We run a matched-filter isochrone (stellar evolutionary track) over distances ranging from 15 kpc to 400 kpc, selecting stars consistent with colors close to the template isochrone for each pixel. We then compute the density of stars in a region of interest and convolve the stellar field with a Gaussian kernel of 2 arcminutes to find significant peaks relative to the background field density. We then visually inspect all candidates identified at the >5.5 sigma significance level.



The above candidate appeared as a significant (9.1 **σ**) overdensity of stars against the density field of foreground stars (top left) and background galaxies (top right). In color magnitude-space (bottom left), this candidate displays a clear main sequence turnoff, lower red giant branch, and blue horizontal branch. The radial profile of stars about the centroid (bottom right) is consistent with the Plummer profile of a compact system with scale extension of ~1 arcmin.

Characterization

We simultaneously fit 9 key morphological and isochrone parameters using the ultra-faint galaxy likelihood software toolkit **ugali** and the affine-invariant Monte Carlo Markov Chain (MCMC) sampler **emcee.**

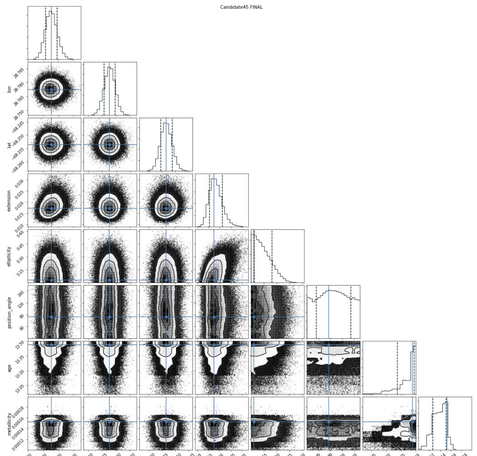
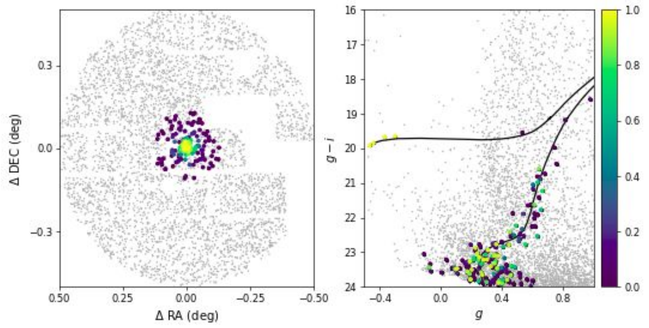


Figure:
Derived 2D posterior distributions for the system's centroid, extension, ellipticity, position angle, age, and metallicity.

These properties appear consistent with known dwarf galaxies; however, there exists some ambiguity in this classification.

Based on the new best-fit parameters, **ugali** then assigns membership probabilities to field stars, as labeled by the color of stars in the figure below.



We also crossmatch the DELVE discovery data with high-precision proper motion data from the *Gaia* satellite. Based on the system's on-sky location and proper motion vector, we find strong early evidence for an association between the candidate system and the Magellanic Clouds. If confirmed, this system would be among the oldest and most metal-poor satellites of the Magellanic System.

References and Acknowledgements

1. https://github.com/DarkEnergySurvey/simple
2. https://github.com/kadrlica/ugali
3. Foreman-Mackey, Daniel et al. "Emcee: The MCMC Hammer." Publications of the Astronomical Society of the Pacific 125.925 (2013): 306–312. Crossref. Web.

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