Selection of Milky Way Analogs Using the Dark Energy Survey

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ABSTRACT

The study of satellite galaxies around Milky Way (MW) analogs is crucial for understanding the structure of galaxies and their dark matter halos. We present the methods used to select a sample of MW analogs using Dark Energy Survey's (DES) Year-Three Release, investigating MW analog galaxies in this footprint for the first time. Our results are compared to a study done with the Sloan Digital Sky Survey (SDSS) on the abundance of satellite galaxies around MW-like hosts. We identify candidates as nearby galaxies ($z < 0.055$) with color $g - r > 0$, apparent magnitude ranging from $11 < r < 17.8$, and an absolute magnitude within +/- 0.25 of the MW. Additionally, we develop a method to remove candidates that have objects brighter than the MW and lie within a chosen angular distance of the candidate galaxy. As a result, we have identified 5894 MW analogs, in comparison to the 8388 from the SDSS study. This will be used to statistically identify the number of satellites around MW-like hosts, an important measurement for classifying dwarf spheroidal galaxies and dark matter subhalos.

INTRODUCTION

The Lambda-Cold Dark Matter (ΛCDM) cosmological model predicts large galaxies to have many dark matter dominated sub-structures orbiting it, known as satellite galaxies. At small scales, there is a discrepancy between the number of observed and predicted satellites which is known as the "missing satellites problem" (Figure 1).

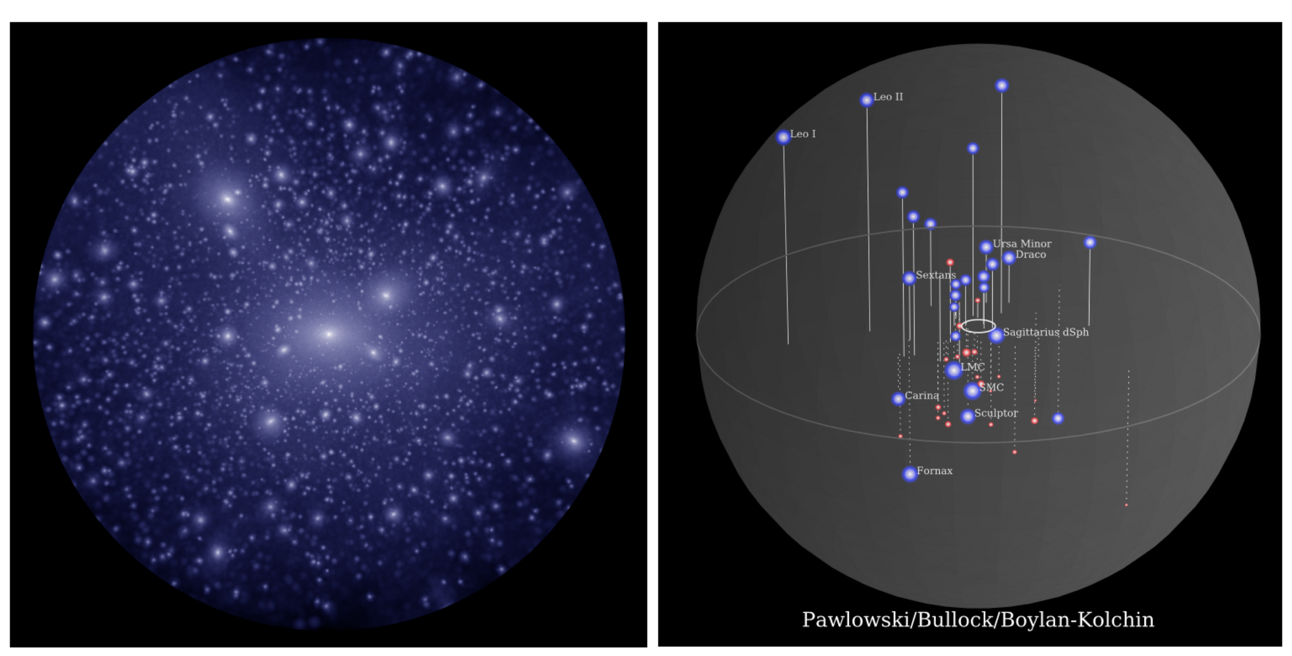

Figure 1. The Missing Satellites Problem: Predicted ΛCMD substructure (left) vs. known Milky Way satellites (right)[2].

We study MW galaxy analogs, or galaxies with similar properties to the MW, to understand if it is a statistical outlier in its population of satellites. Strigari et al., 2012 found 8388 analogs with their corresponding satellites with the SDSS dataset. Therefore, with the coverage and depth of the DES, we expect to significantly increase the number of host galaxies observed, and find satellites fainter than the limit of SDSS[1].

METHODS

We acquire the data from DES Year 3 Science Release, as multi-extension fits files reduced using numerical techniques in python. Although this study consists of galaxies with apparent magnitude $11 < r < 17.8$, we look closely at galaxies between $15.8 < r < 16.8$ to apply the reduction methods. Specific cuts are made on absolute magnitude +/- 0.25 of the MW (M_r = - 20.4), as well as redshift ($z < 0.055$) and color ($g - r > 0$)[1]. We compare the color magnitude diagram of the SDSS and DES datasets to make sure the sample is in agreement with the previous study of Strigari et al., 2012 (Figure 2).

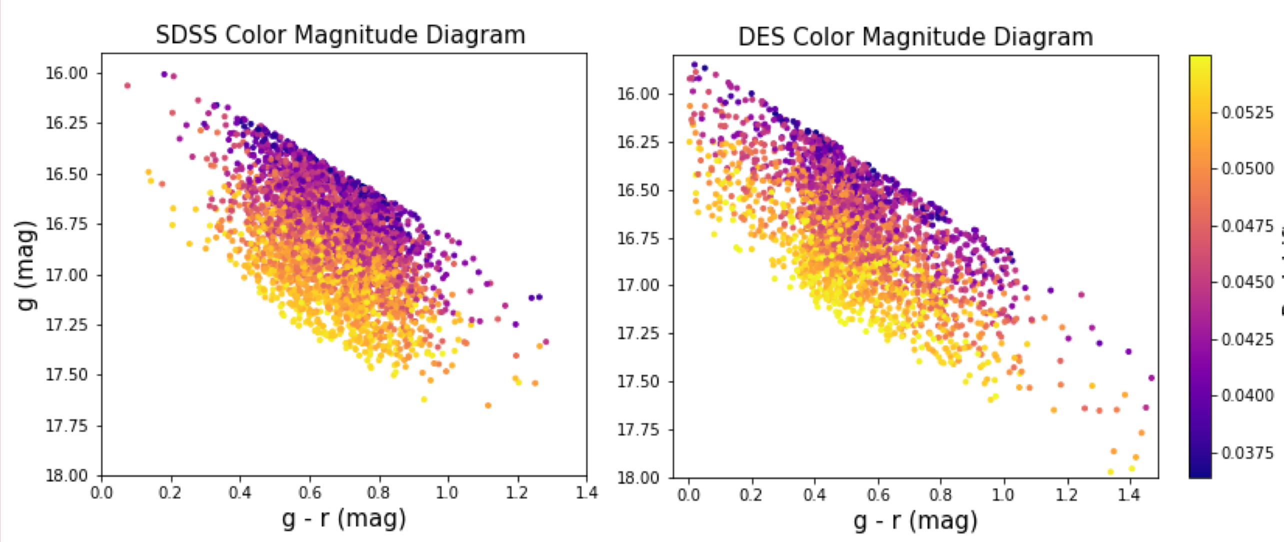

Figure 2. Color Magnitude Diagrams for candidate galaxies from $15.8 < r < 16.8$ for the SDSS sample with 3,244 objects (left) and DES data with 2,268 objects (right).

ISOLATION CRITERIA

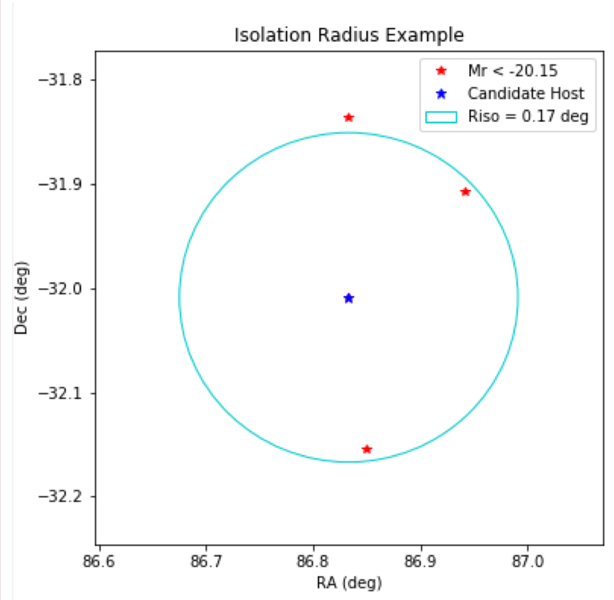

Figure 3. Schematic diagram of a candidate galaxy with nearby objects brighter than the MW, and the isolation radius that serves as the cutoff.

To exclude galaxies that are not isolated like the MW, we remove galaxies of absolute magnitude brighter than the MW ($M_r < -20.15$) and within a physical radius (R_{iso} = 0.5Mpc) at the redshift of the candidate. The isolation radius is an angle in the sky and is determined by:

$$\sigma = R_{iso}/d_A$$

where

$$d_A = c \cdot H_0 \cdot z \cdot (1 - 1.225 \cdot z)$$

RESULTS

The results for the number of analog galaxies found in SDSS and the number found in this project are shown in Table 1. We finalize our sample with **5894 analogs** from DES. We expect the final sample to be less because of the smaller survey size of DES ~5000 deg^2.

Apparent Magnitude	Host Sample (SDSS)	Host Sample (DES)
11 < r < 11.8	49	0
11.8 < r < 12.8	99	15
12. 8 < r < 13.8	579	246
13.8 < r < 14.8	2000	2243
14.8 < r < 15.8	4847	1122
15.8 < r < 16.8	814	2268
16.8 < r < 17.8	0	0
Total	8388	5894

Table 1. Number of analog galaxies found in SDSS and DES.

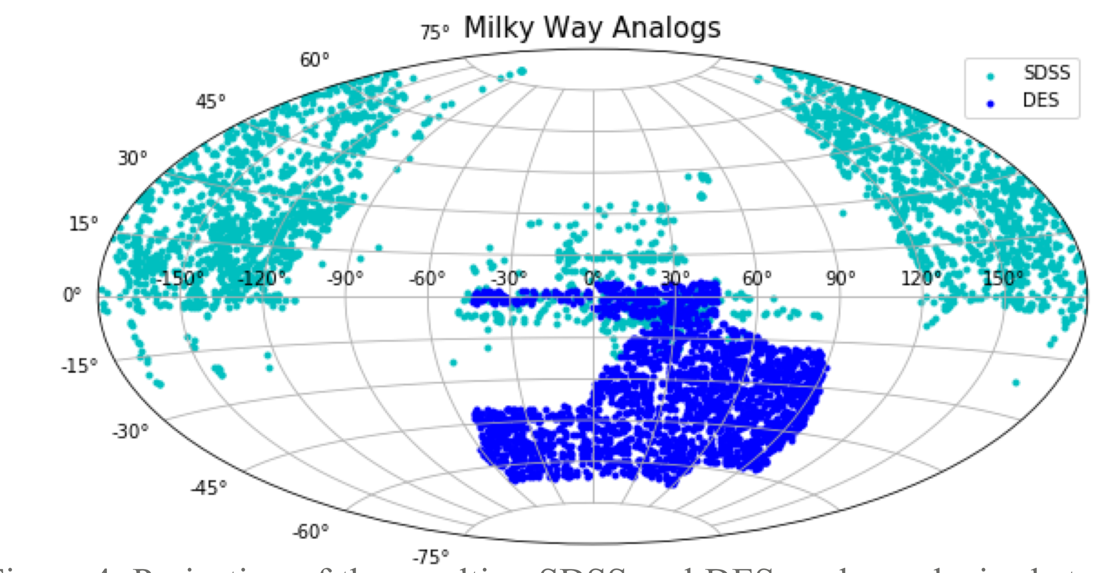

Figure 4. Projection of the resulting SDSS and DES analog galaxies between apparent magnitudes $15.8 < r < 16.8$.

The location of the sample with all conditions applied is shown in an aitoff projection in Figure 4. An important step is to visually inspect the galaxies to verify the removal of candidates that could be part of another satellite system. The images in Figure 5 show two successfully chosen MW analogs, and two discarded candidates. Most selected analog galaxies are in agreement with the expected isolation outcome.

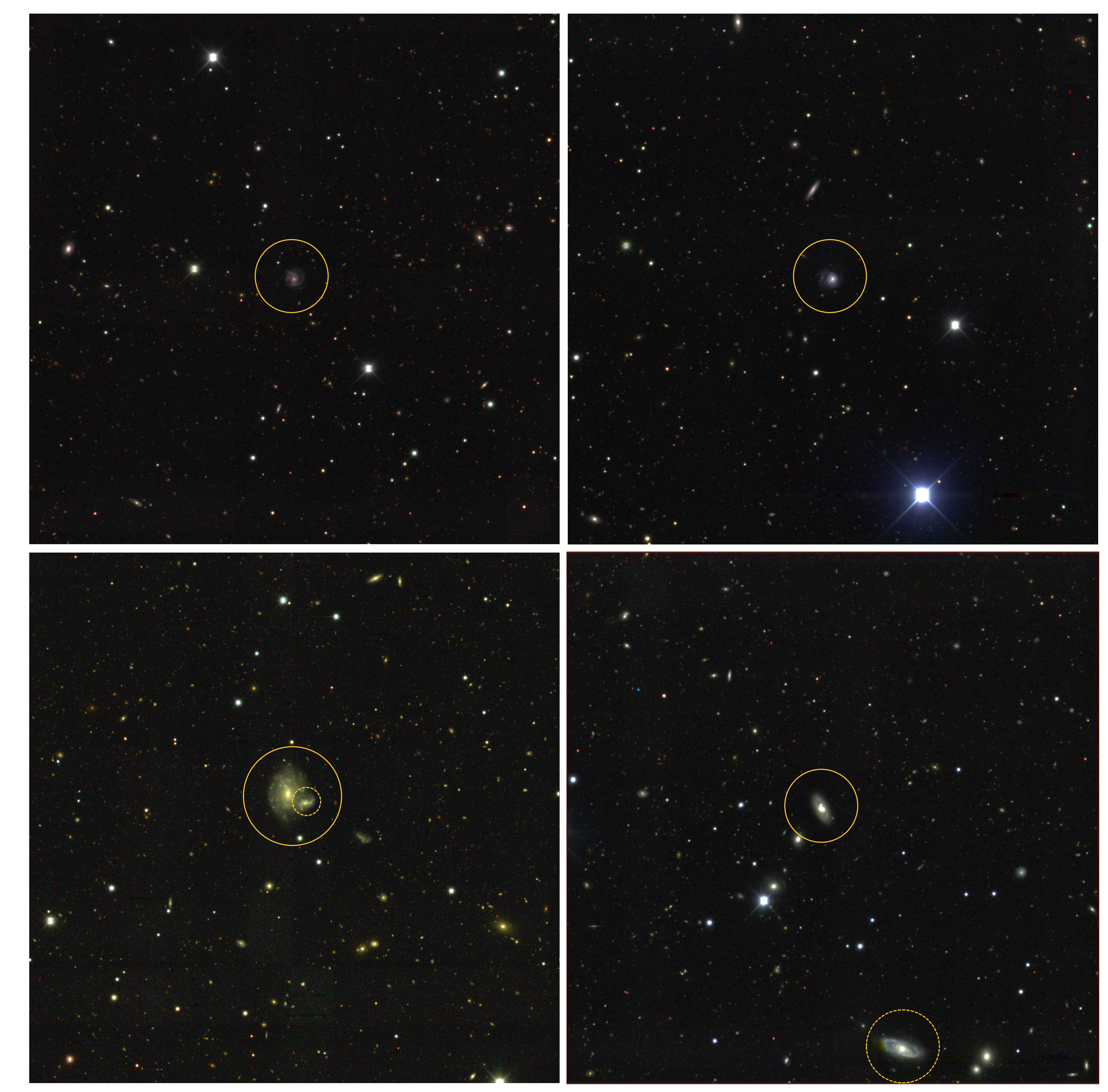

Figure 5. A 10x10 arcmin image of two selected MW analog galaxies (top) and two candidate galaxies (bottom) with one bright object nearby from the DES Cutout Service[3].

CONCLUSION

The final list of MW analog galaxies needs to be further inspected to be ensure the numerical methods introduced in this project are correct. For future work, we expect to revise the photometric data, utilize it at fainter magnitudes, and search for the number of satellites around each MW analog.

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