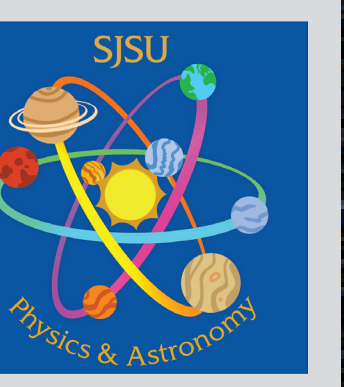# New Search for Dark Matter Free Dwarf Galaxies using Legacy Imaging

Yashraj Bains & Aaron J. Romanowsky, San José State University Physics & Astronomy Department

Abstract: NGC 1052 DF2 and DF4 are two well-studied dwarf galaxies which have been determined to contain little to no dark matter. Using Legacy imaging data, we are conducting a new search for dark matter free dwarf galaxies which share similar properties to these dwarfs. The primary property we are focusing on is the presence of unusually luminous globular clusters, understood to be closely connected to the formation of these galaxies which lack dark matter.

Background

The only known dark matter free dwarf galaxies are NGC-1052 DF2 and DF4 (van Dokkum et al. 2018, 2019). These dwarf galaxies seem to exhibit a pattern of hosting overly luminous globular clusters (GCs; Shen et al. 2021). Publicly available Legacy Imaging Survey images these objects with great clarity, although Legacy model photometry does not work for GC analysis because of the shredding problem (see Figure 1).

The goal is to utilize publicly available Legacy data to characterize these clusters, developing a search for similar clusters in other visually similar dwarfs. If a dwarf is found to contain these unusual clusters, it may suggest that the galaxy contains little to no dark matter. These candidates can then be further studied using more advanced imaging such as Hubble.

Once the search is optimized to select most of the confirmed GCs while minimizing the amount of contaminants, we will automate a search through catalogs of thousands of galaxies, returning any which contains enough unusual GCs to suggest it may be a dark matter free candidate.

Methods

Legacy's DR10 photometry data was collected for DF2 and DF4, as well as an additional strong dark matter free candidate: FCC 224. 3 primary plots were created in order to determine our selection parameters, including magnitude vs color, magnitude vs concentration, and color vs concentration.

When data from the known globular clusters within these galaxies were plotted along with Legacy sources, selection boxes were created which defined the parameters within which these clusters exist. The parameters were decided as follows: 0.75 arcsecond aperture magnitude in the *g*-band between 22.5 - 24, concentration (1-3 aperture difference) between 0.7 - 1.3, and *g-i* color between 0.75 - 1.2.

The selected parameters are input into Astro Data Lab's Query Interface and the result is formatted and uploaded to the Legacy Viewer, where the accuracy of the results is studied by cross-referencing the selected points to a catalog of confirmed globular clusters. This process of choosing selections and analyzing the results was done multiple times in order to optimize the search to select as many confirmed GCs as possible while minimizing the amount of

Results and Future Research

This search is still ongoing, although the initial results show promise and trend towards soon being able to provide evidence to whether or not a galaxy contains dark matter. Analysis on photometry data from galaxies DF2, DF4, and FCC 224 is near completion and selection parameters are being finalized. Next steps are to test the search on unstudied dwarf galaxies at similar distances to the known dark matter free galaxies. Once the search is manually tested on a handful of galaxies and further optimized, steps will be taken to automate the search in order to search through catalogs of thousands of dwarf galaxies.

Figure 1: The image on the left displays NGC-1052 DF2 with the most recent SQL query performed. All true GCs are properly captured, though 5 contaminants are picked up as well. To the right of this image is the Legacy model. A closer look reveals the "shredding" problem - the galaxy looks "patchy." This is one of the motivations for creating the plots below to understand which parameters will work best to isolate true GCs.
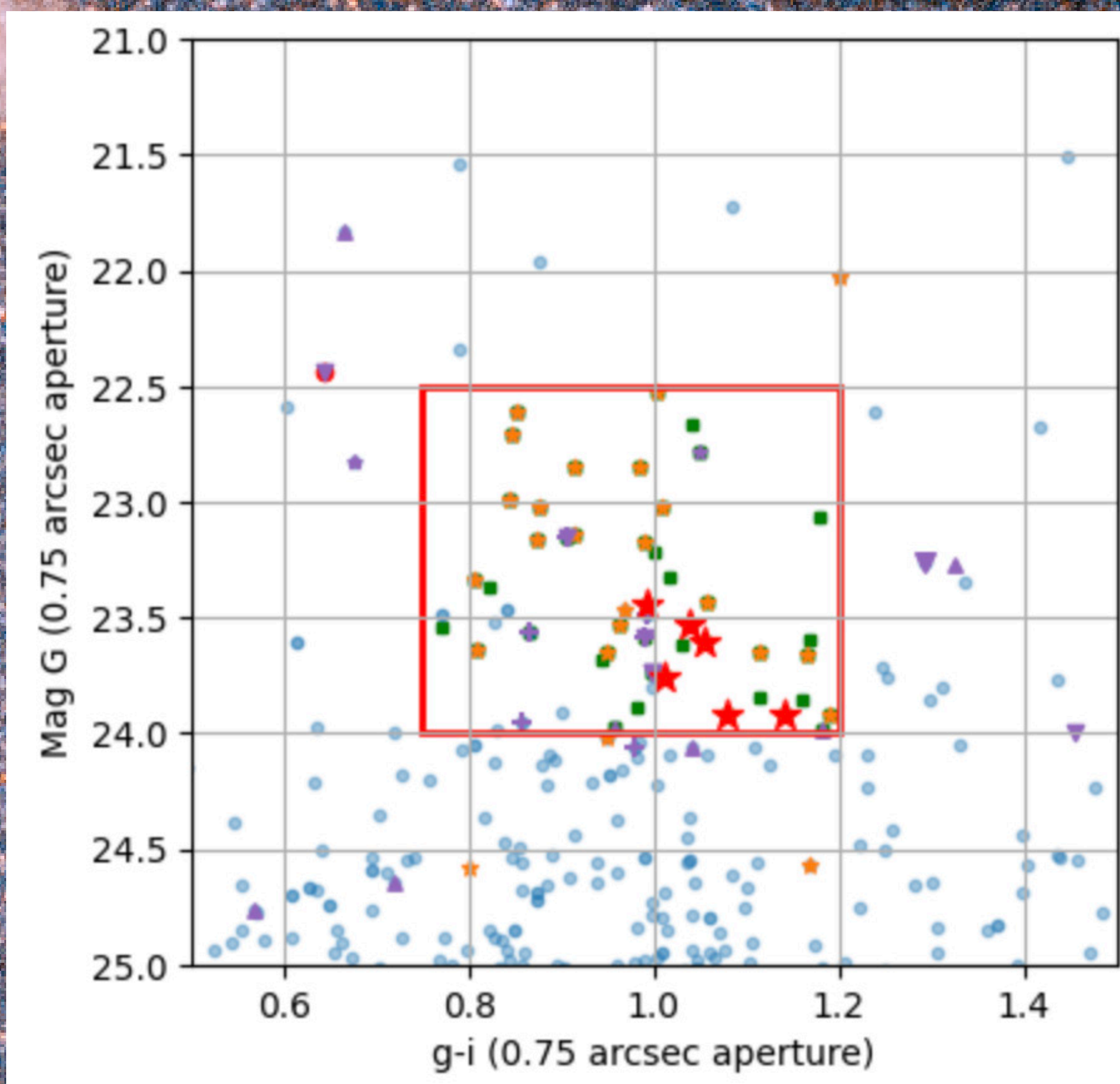

Figure 2: Plot showing magnitude vs color, both using 0.75 arcsecond apertures which were determined to be most accurate when compared to literature values. Confirmed globular clusters are plotted alongside all point sources within the search radius as well as known contaminants. A selection box is drawn to capture the most confirmed clusters possible while minimizing the amount of contaminants.
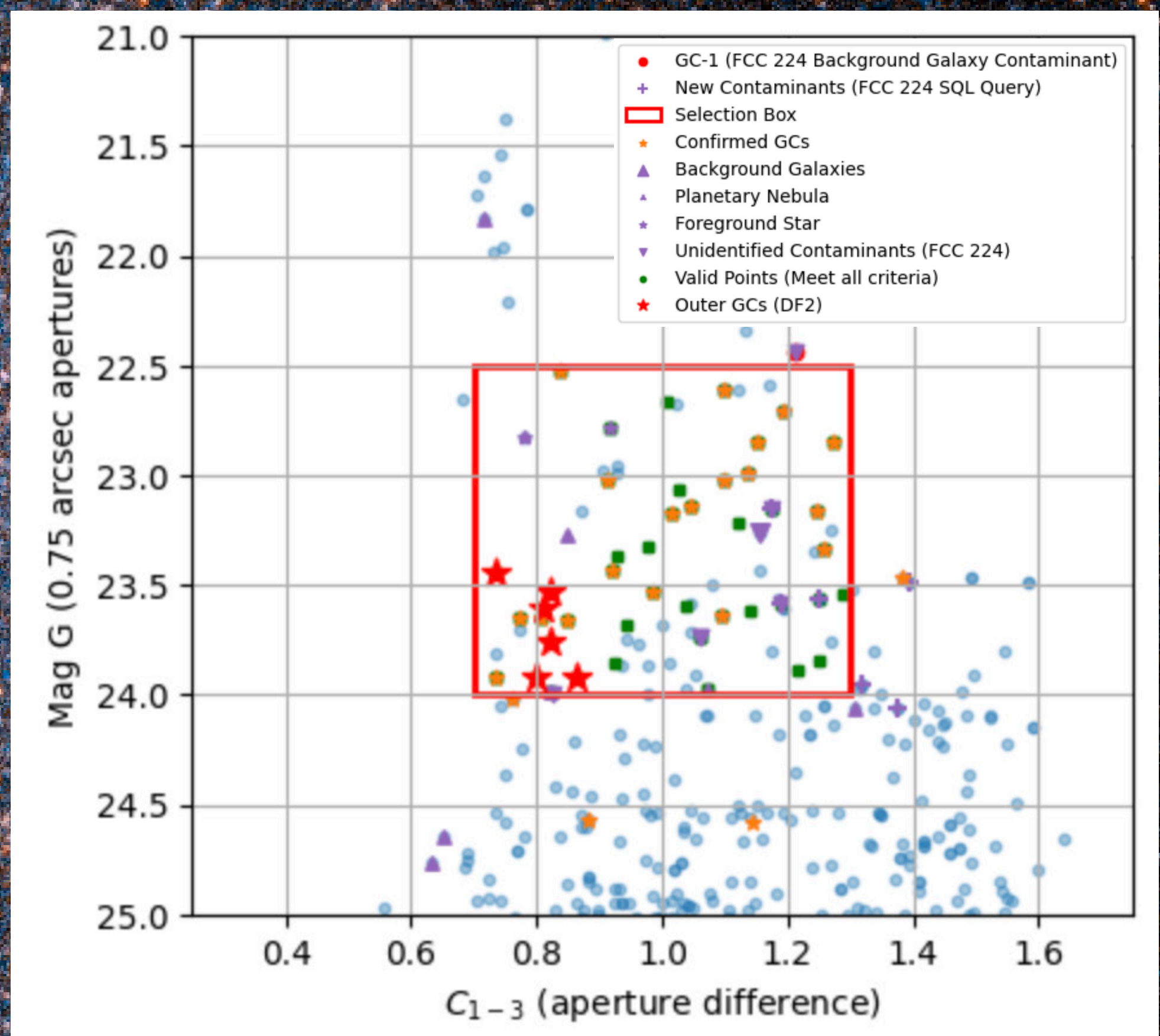
Figure 3: Again, photometric data from Legacy Imaging is plotted with special objects such as confirmed GCs and contaminants highlighted. Final selections of *g*-band magnitude between 22.5 and 24.0, and concentration between 0.7 and 1.3 were determined.
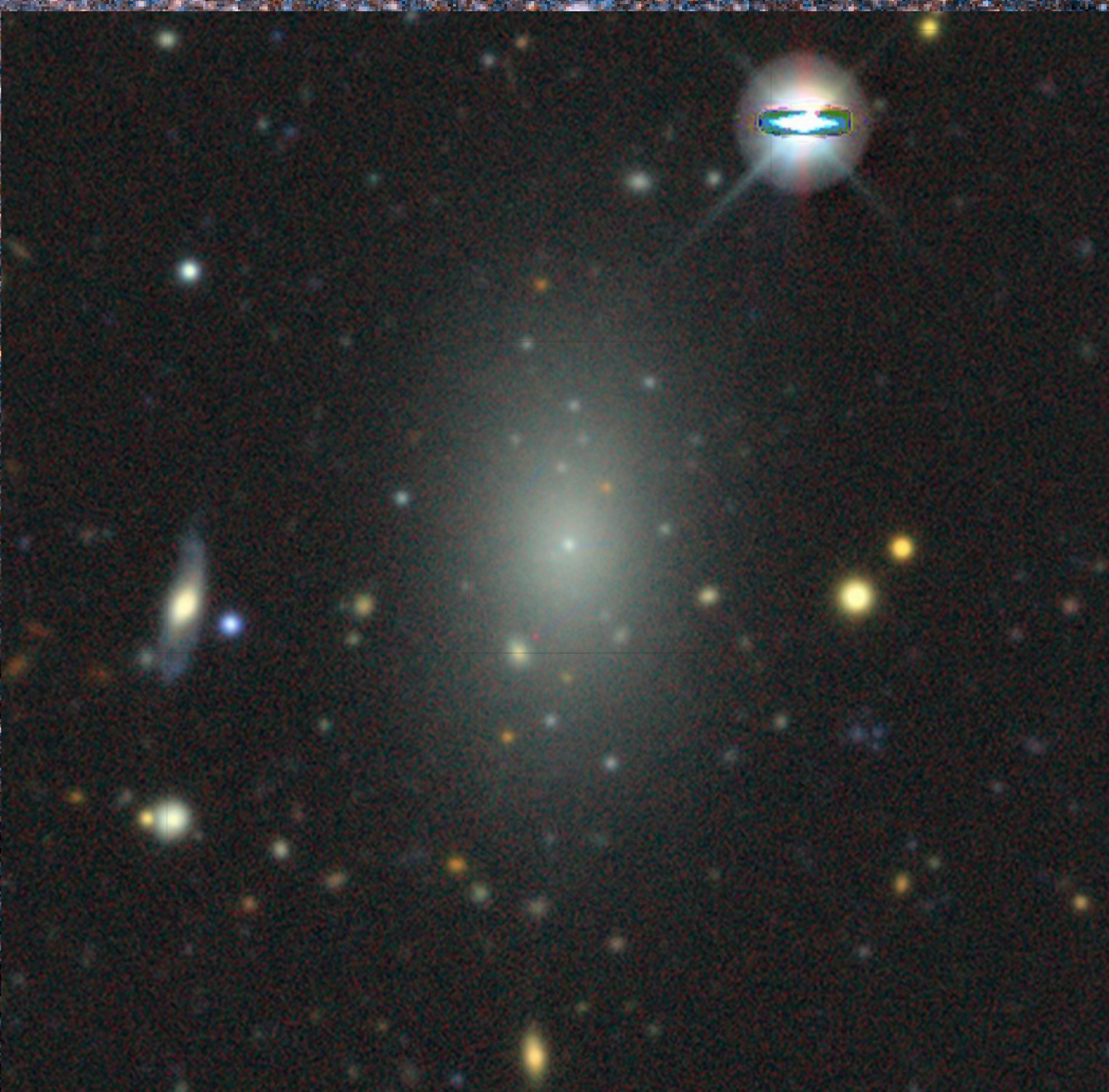

Figure 4: Pictured is another dwarf galaxy with an apparent abundance of bright GCs. Running an object like this through the finalized query could point out interesting clusters and give empirical evidence as to whether or not it could be a candidate for a dark matter free galaxy.
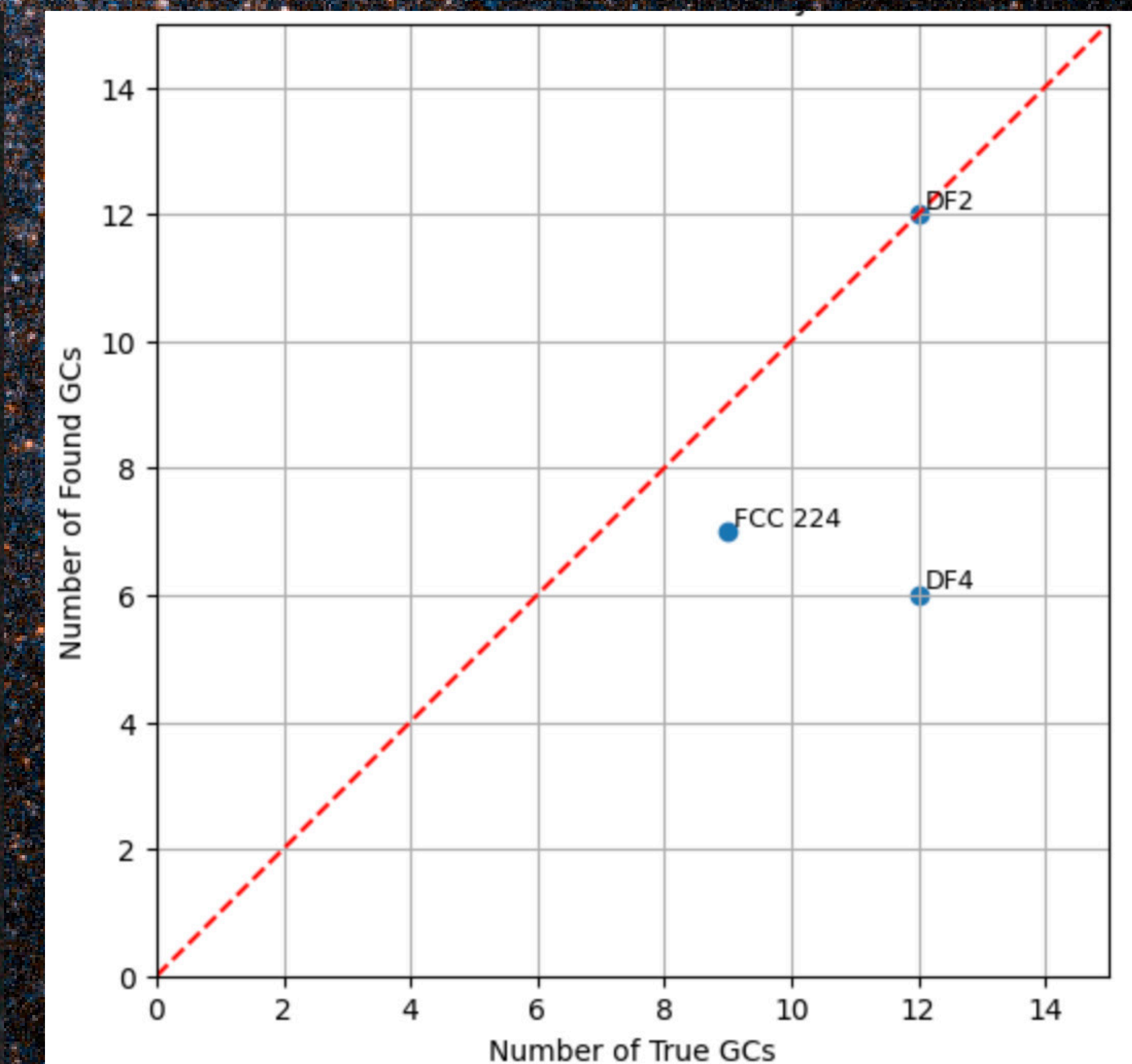
Figure 5: Within the two known dark matter free candidates, DF2 and DF4, and the strong dark matter free candidate, FCC 224, there is a promising 1:1 trend between number of true GCs in the galaxy and number of GCs successfully picked by the new search.

References

Astro Data Lab. Astro Data Lab - Query. (n.d.). https://datalab.noirlab.edu/query.php

Legacy survey sky browser. (n.d.). https://www.legacysurvey.org/viewer/?ra=40.4378&dec=-8.4234&catalog=tmp7ruqq4eh

Nikutta et al. (2020), A&C, 33, 100411

Shen et al. (2021), ApJ, 909(2), 179.

van Dokkum et al. ApJS, 874(1)

van Dokkum, P., Danieli, S., Cohen, Y., Merritt, A., Romanowsky, A. J., Abraham, R., Brodie, J., Conroy, C., Lokhorst,

van Dokkum et al. Nature, 555(7698) 629-632