# Establishing Membership Probabilities and Searching for Extra-Tidal Stars of Cluster NGC 6569

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**Fig. 1:** Observed image of cluster NGC 6569. *DSS2*

## Why do we care about star clusters?

The Milky Way Galaxy hosts billions of stars, most of which formed billions of years ago within large star clusters. Like the Earth around the Sun, these clusters orbit the galaxy's center of mass, with each orbit spanning hundreds of millions of years.

Over time, the Milky Way's strong gravitational forces strip stars from their parent clusters, ejecting them onto new orbits. By tracing these extra-tidal stars and analyzing their orbital trajectories, we can reconstruct the history of each clusters' orbit. This will allow future work to rewind the clock of galactic dynamics and better understand the history of the Milky Way. The first piece of this task, and the primary objective of this research, is to accurately identify these stripped stars as members of their original clusters.

## How the membership process works

### Binning of data in 5-dimensions

- We utilize BDBS[1] observations of the field containing NGC 6569. We also use the Besancon Galaxy Model[2] to produce a simulated field star population for the area around the cluster
- We bin the data across five dimensions—three for position and two for motion—and compile a list of unique combinations that potentially describe one or more stars in each dataset

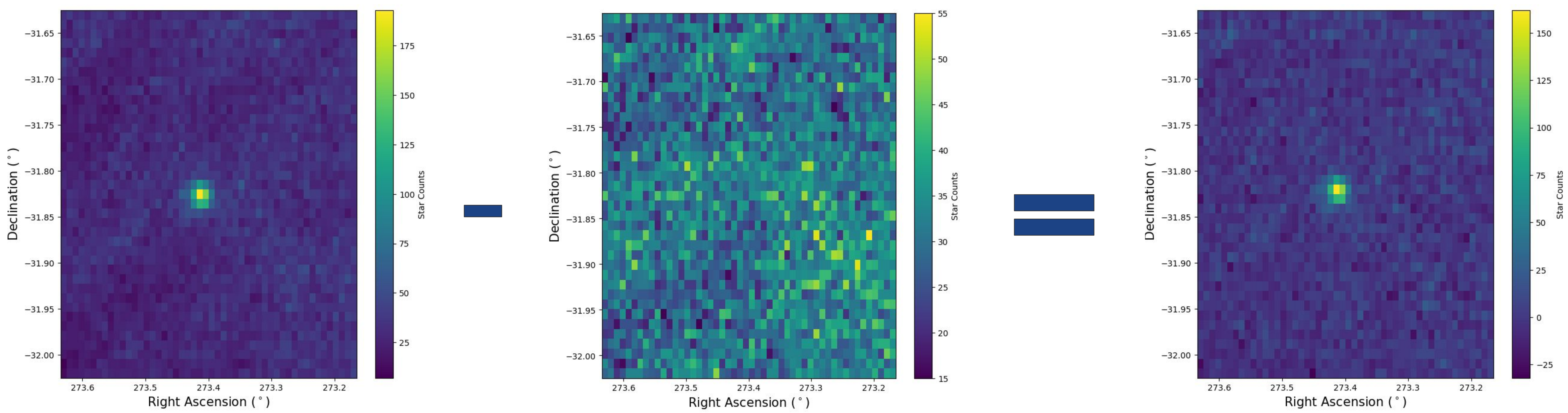
### Subtraction of datasets

- To isolate potential cluster members, we subtract the Besancon model from the observed data
- The subtraction is done across the 5D parameter space, but 1D or 2D projections can be viewed for comparison like below

### Identifying potential members

- After subtraction, cluster stars will be present in statistical overdensities found in the residual arrays
- We apply a localized RMS calculation to compare the number of stars in each voxel with the neighboring voxel to determine the statistical significance of any excess
- The membership probability is calculated as the ratio of cluster stars to field stars within each voxel, and assigned to each star found there

$$membership\,probability = \frac{\#\,of\;cluster\;stars}{\#\,of\;field\;stars}$$




**Figures 2,3,4:**
Each figure displays a positional density plot, with the left generated from observational data, the middle from simulated data, and the right showing the result of their subtraction. The cluster is distinctly visible in the residuals plot (right), while background stars are largely absent.

## What we learned

### Subtraction reveals potential cluster stars

- In both position and proper motion space, subtracting away the datasets revealed clear indications of the cluster, with hints of a tidal tail present in positional space

### Sensitivity of bin count

- Our process generates a total of 11 million unique voxels in the 5D space where a star can be found. With only 60,000 stars in a dataset, this results in the majority of voxels being empty while populated voxels typically have just one star

## Next steps and iterations

### Cluster likelihood map

- We will use the Gala[3] mockstream generator to produce a synthetic cluster, indicating where cluster stars are expected in the absence of a field star population

### Incorporating new dimensions

- Combining photometric and kinematic membership probabilities will significantly enhance the robustness of the membership probability estimates

## Acknowledgements and references

This work has been made possible by the generous contributions of the RAISE foundation that is aimed at boosting the productivity of research being pursued at private undergraduate colleges and universities in the Pacific Northwest. We also thank the Jarvis Memorial Summer Research Award for affording us the opportunity to add an additional member to our research team this year.

1. The Blanco DECam Bulge Survey Collaboration
2. Robin et al 2003, A&A, 409, 523
3. Price-Whelan 2017, JOSS, 2, 383