A machine-learning led search for extra-tidal stars of globular clusters

SURP Project by: Ryan Wang[1]
Supervised by: Dr. Joshua S. Speagle[1,2,3,4], Dr. Jeremy J. Webb[5]

1. Department of Statistical Sciences, University of Toronto
2. David A. Dunlap Department of Astronomy & Astrophysics, University of Toronto
3. Dunlap Institute for Astronomy & Astrophysics, University of Toronto
4. Data Sciences Institute, University of Toronto
5. Department of Science, Technology, and Society, Division of Natural Sciences, York University

Why we love globular clusters!

- Globular clusters (**GCs**) are an ideal environment to learn about **star cluster evolution** and **internal interactions**.
- The study of **mass loss** constrains the conditions of **formation** and **evolution** and provides key insights on tracing back the largely unknown **histories** of GCs.
- One significant source of GC **mass loss** occurs through the **ejection** of cluster stars beyond the tidal radius: **extra-tidal** (**ET**) stars.
- These **escaped stars** can be traced back to **parent GCs** to quantify the **mass loss** of a cluster and reproduce the **characteristics** of galactic **star forming regions**.

The mission: Find those ET stars!

- Identification of **cluster member stars** for each GC using **spatial**, **chemical**, and **kinematic** similarities through a **machine-learning** led **dimensionality.**
- **Chemical** analysis of field stars to find **extra-tidal** stars with similar **compositions** beyond the tidal radius.
- **Streamline** and **automate** the process using **machine-learning** driven approaches in latent space **clustering.**
- **Validation** of results using a **metallicity-based** analysis.

Presenting:

An automated, chemistry-based extra-tidal star detection pipeline for any globular cluster

The Pipeline

Step 1: Locate spatially similar cluster member candidates

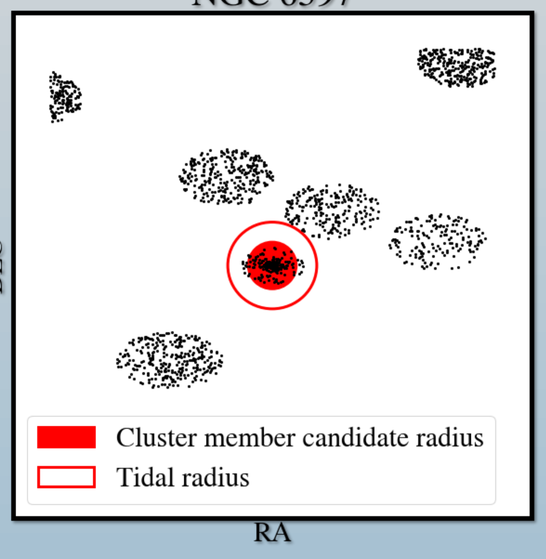
Step 2: Locate kinematically and chemically similar cluster members

Step 3: Clustering in latent space with DBSCAN

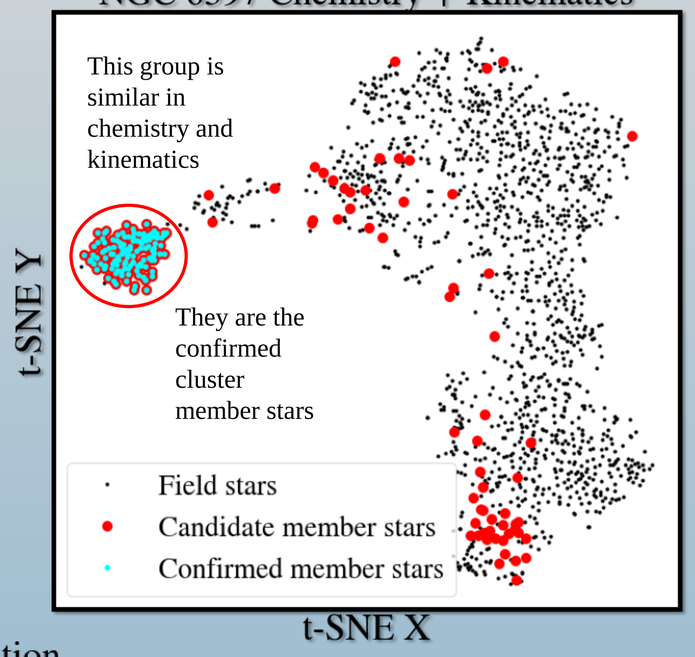
Step 4: Locate chemically similar stars to confirmed cluster members

Step 5: Tidal radius cut for final extra-tidal stars

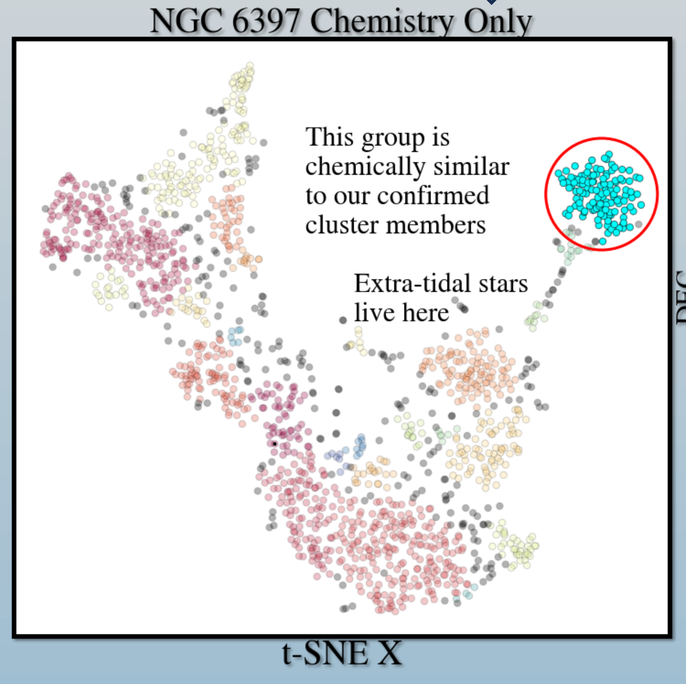
NGC 6397



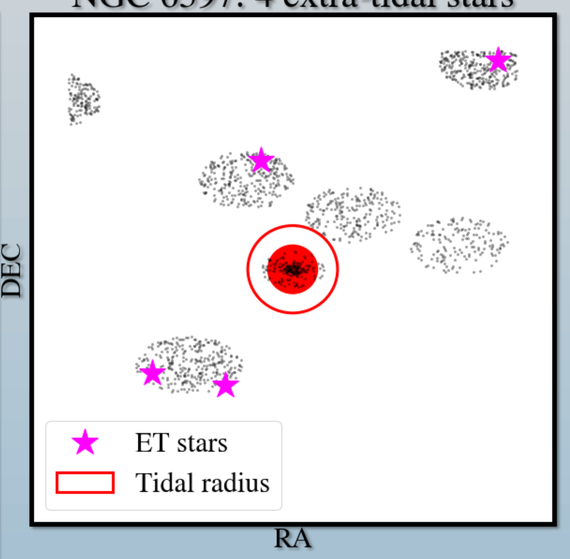
NGC 6397 Chemistry + Kinematics



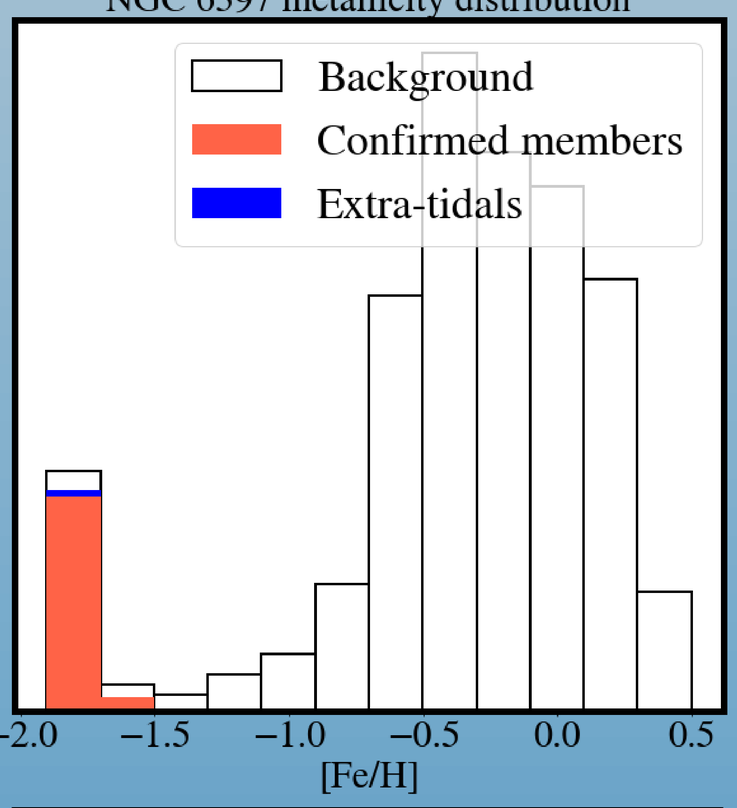
NGC 6397 Chemistry Only



NGC 6397: 4 extra-tidal stars



NGC 6397 metallicity distribution



Most of the field stars have a primary spike around a metallicity of 0, while the **confirmed cluster member** stars and **extra-tidal** stars both populate a **secondary peak** at a **lower metallicity**. This indicates that they both belong to a **distinct metallicity group** likely attributed to the **globular cluster population**.

34 total clusters

25 successful extra-tidal identifications

830 extra-tidal stars identified

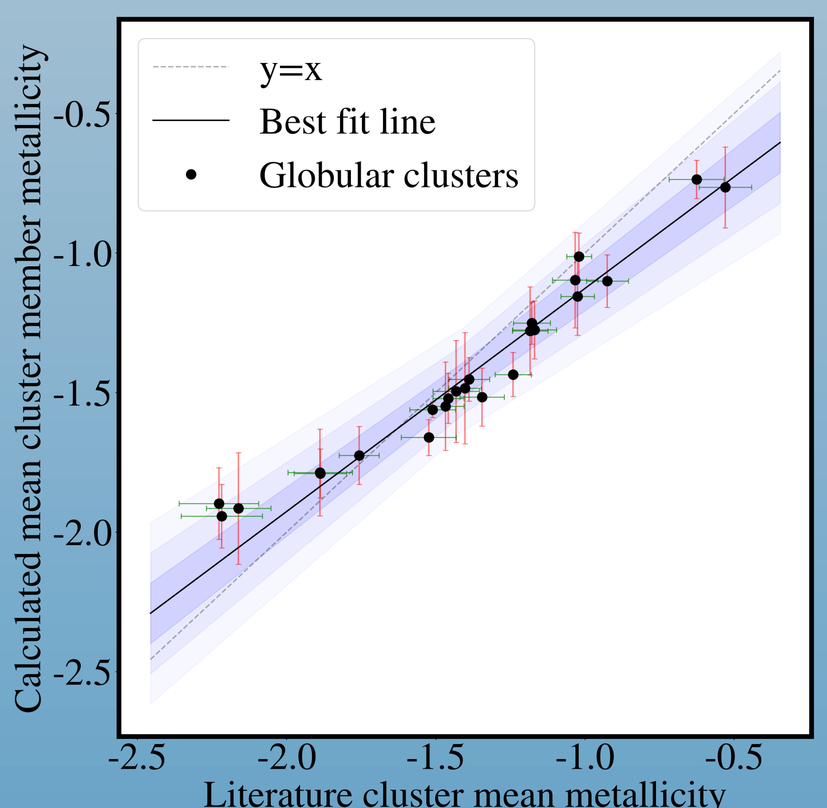
Future work

Inclusion of **other surveys** such as GAIA DR3 or APOGEE DR18 (once abundances have been derived) for more **complete GC coverage.**

Star cluster escape simulations to determine an estimated number of ET candidates per GC to quantify the effect of survey bias.

Tests using trios of abundances, fixing [Fe/H] as a main driver and varying the other two and comparing results.

Follow up analysis with CMD and/or statistical analysis based on kinematic properties of identified ET stars.



The mean **metallicity** of the **confirmed cluster member** stars **match up well** with the **literature metallicity** values for **all 25 successful clusters.** As each cluster **field** is **isolated** from one another, the **similarities in metallicity** likely indicate that the **confirmed cluster members correspond** to the **globular cluster** itself.

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