

Dynamical Relics with r-process Enhanced Signatures from Ancient Small Dwarf Galaxies

**Zhen Yuan
(SHAO, postdoc)**

Collaborators:

Tadafumi Matsuno (NAOJ)

Kohei Hattori (U of Michigan)

T.S. Li (Fermi Lab)

Haining Li (NAOC)

Martin Smith (SHAO)

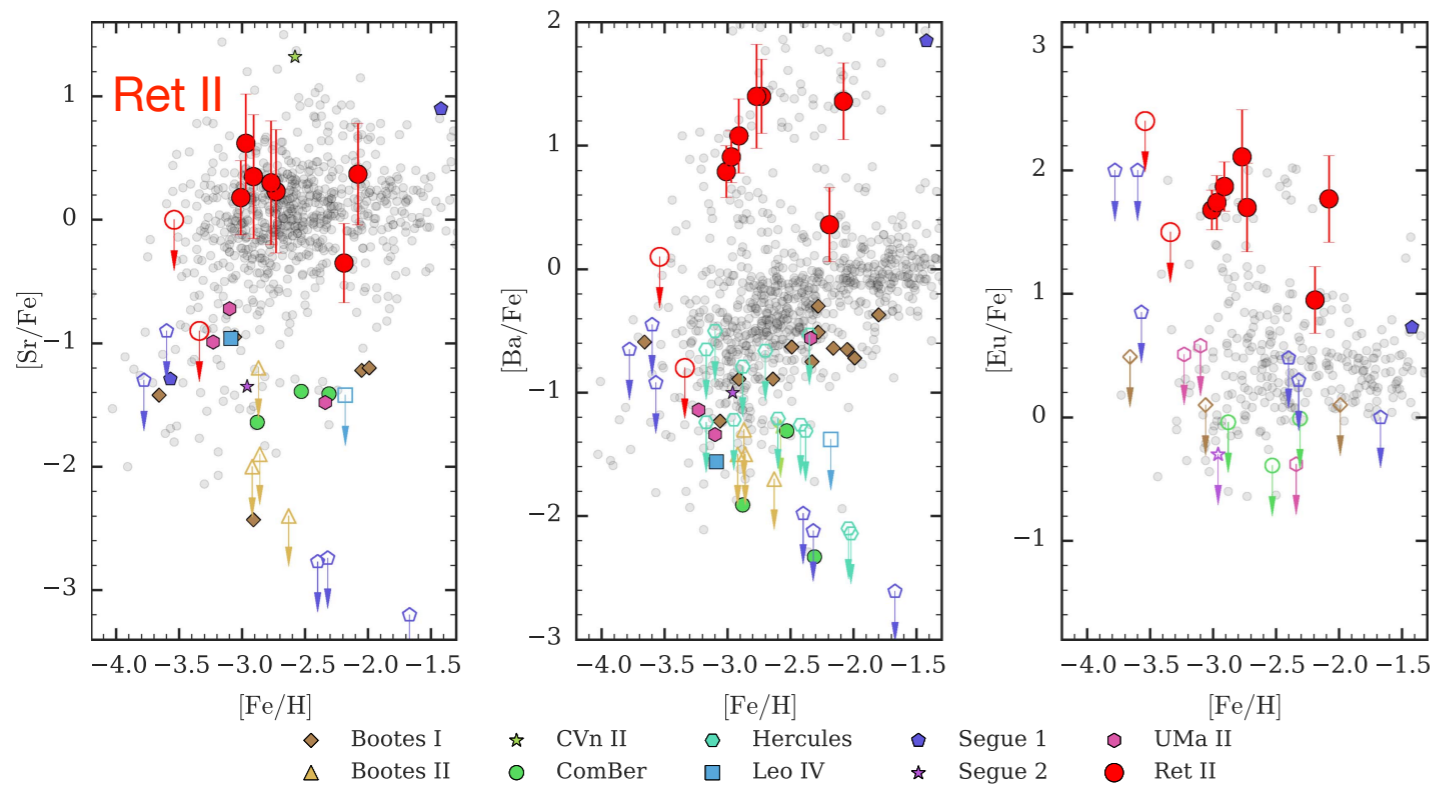
Projjwal Banerjee (SJTU)

R-process enhanced elements

Rare Supernovae

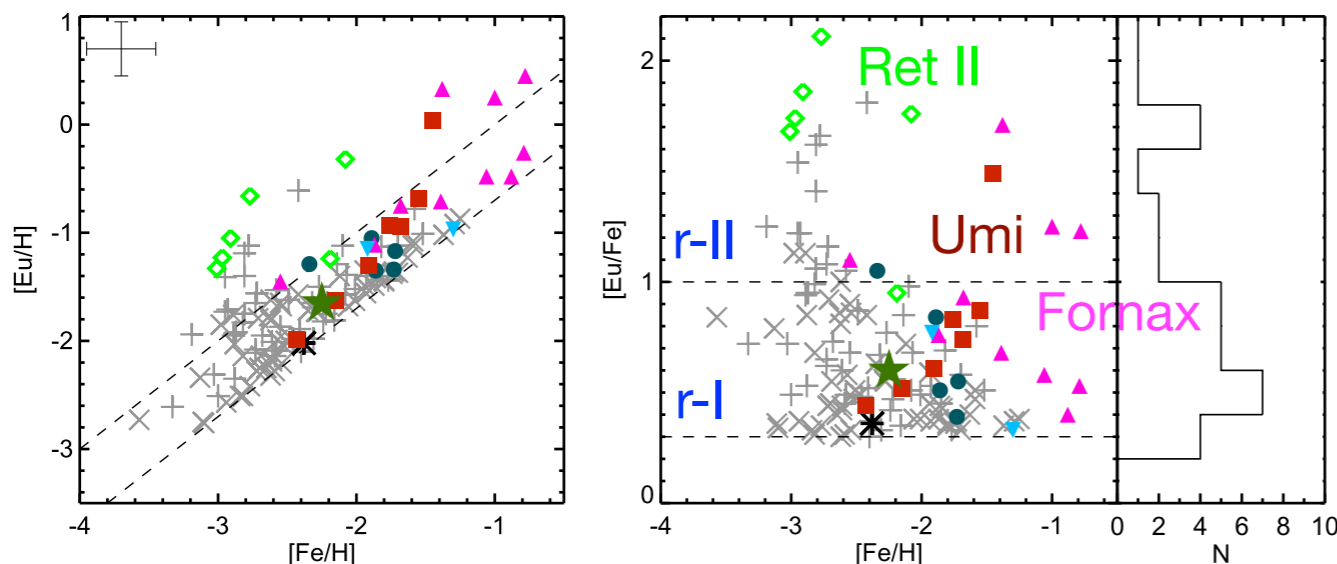
Neutron Star Merger (confirmed)

High resolution spectroscopic in Halo + Dwarfs



Ji et al. 2017

1. Halo & Dwarfs → Hierarchical formation history
2. Large scatter below $[Fe/H] = -2$ can be explained by rare events
3. All UFDs have very deficient values of r-process element, except for Ret II, which have highly r-process enhanced stars → rare prolific event
4. Normal dwarfs have variations in r-process values → multiple events
5. Inhomogeneous mixing in UFD



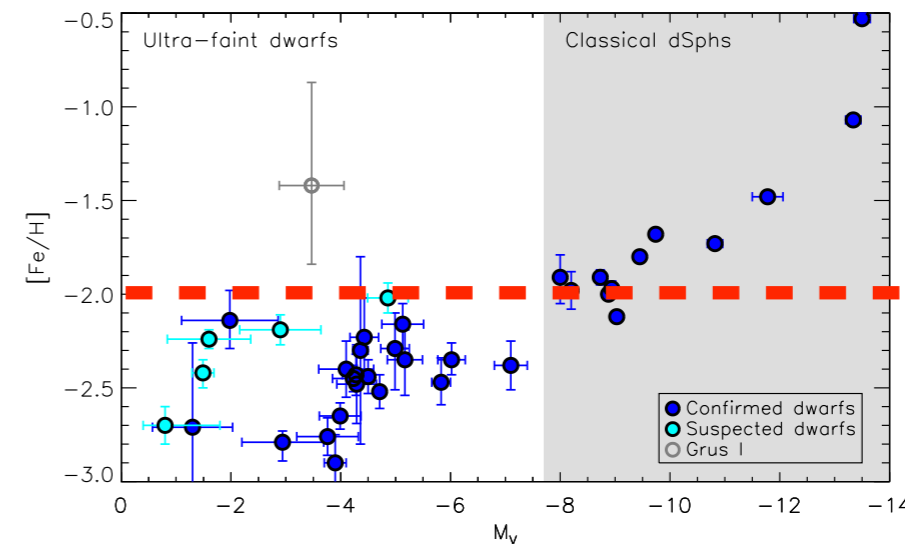
Hansen et al. 2017

Motivations:

- Understanding UFD as the host site of r-II stars from the stellar halo (the birth environment and enrichment scenario).
- Yields? Frequency? Natal kick velocity? Dominant channel and Abundance patterns? (NS+BH, NS+NS, SN)

Plan:

- Find the substructures that the r-II halo stars belong to.
- Most of the r-II stars come from UFDs \rightarrow Debris of UFD in the stellar halo.
- \rightarrow More r-II candidates



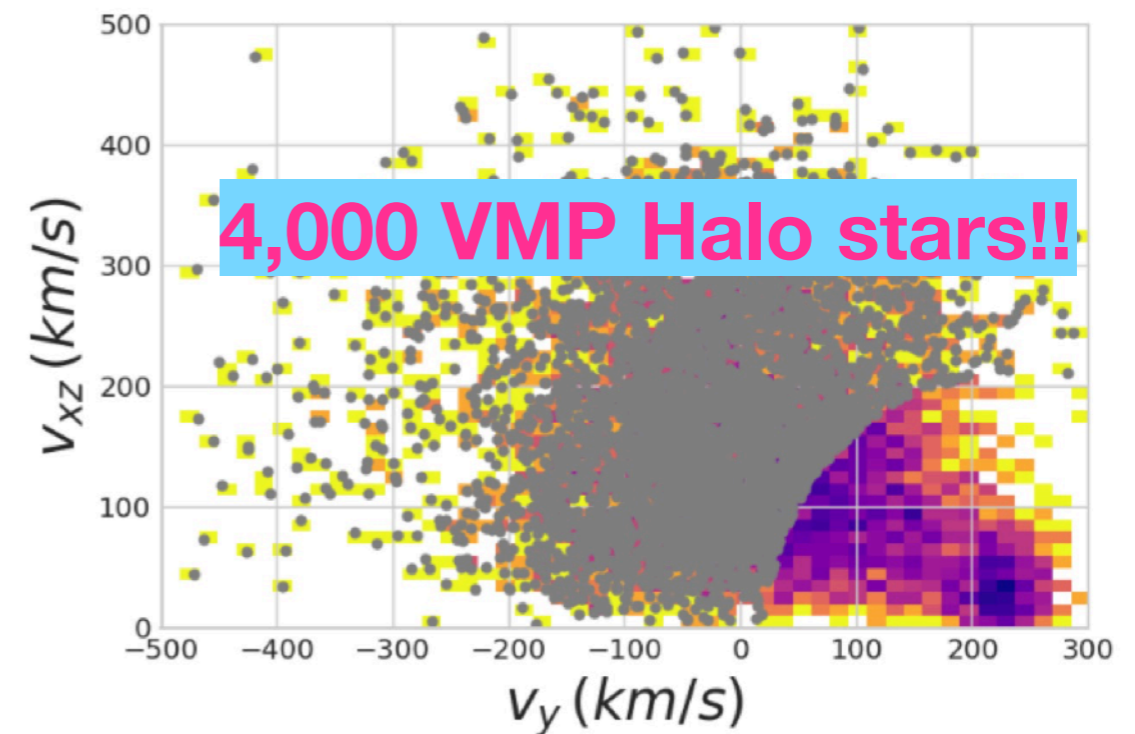
Simon 2019

LAMOST DR3 VMP

Li, H.-N., Tan, Zhao 2018

Li, H.-N., Aoki, Matsuno 2018

The largest bright VMP catalog of 10,000 stars, with metallicity uncertainty ~ 0.3 dex

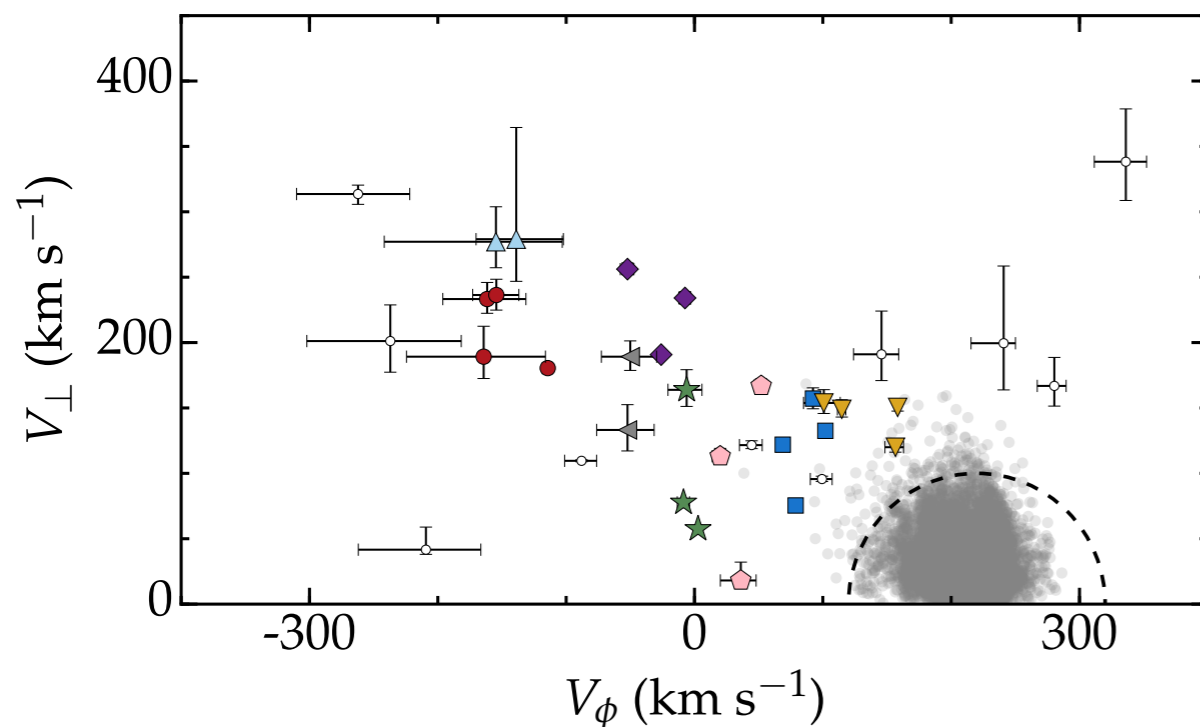


parallax_over_error ≥ 5

parallax ≥ 0.2

Toomre Diagram

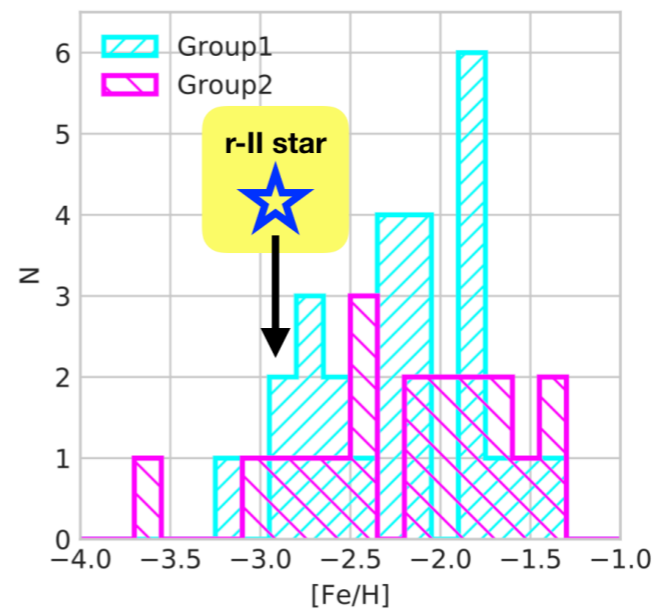
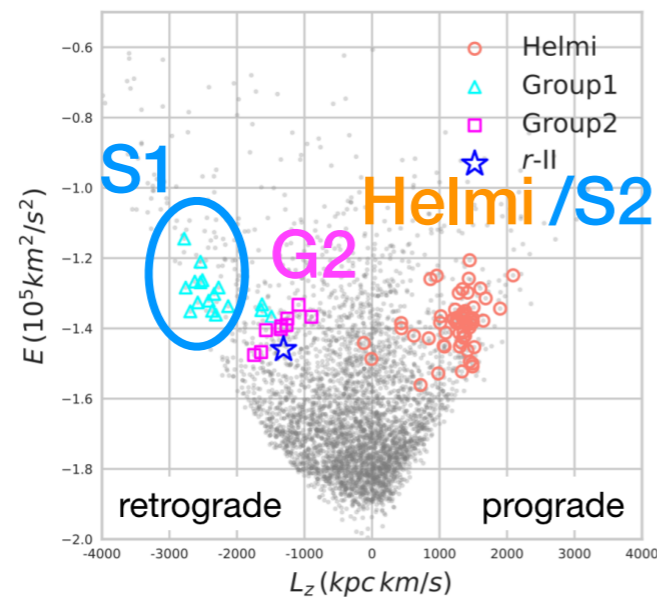
All the r-II have Halo Kinematics



Roederer, Hattori, Valluri 2018

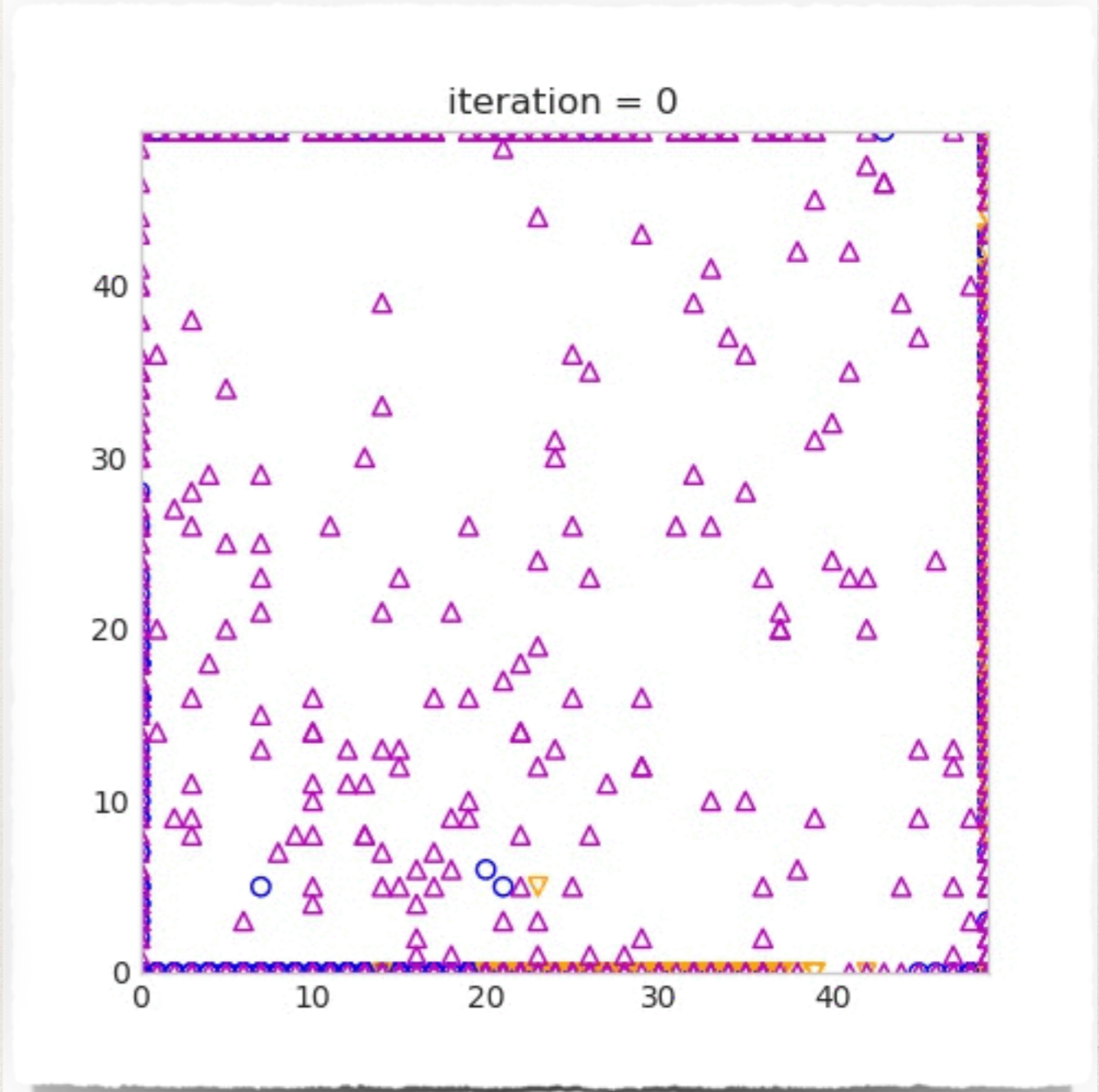
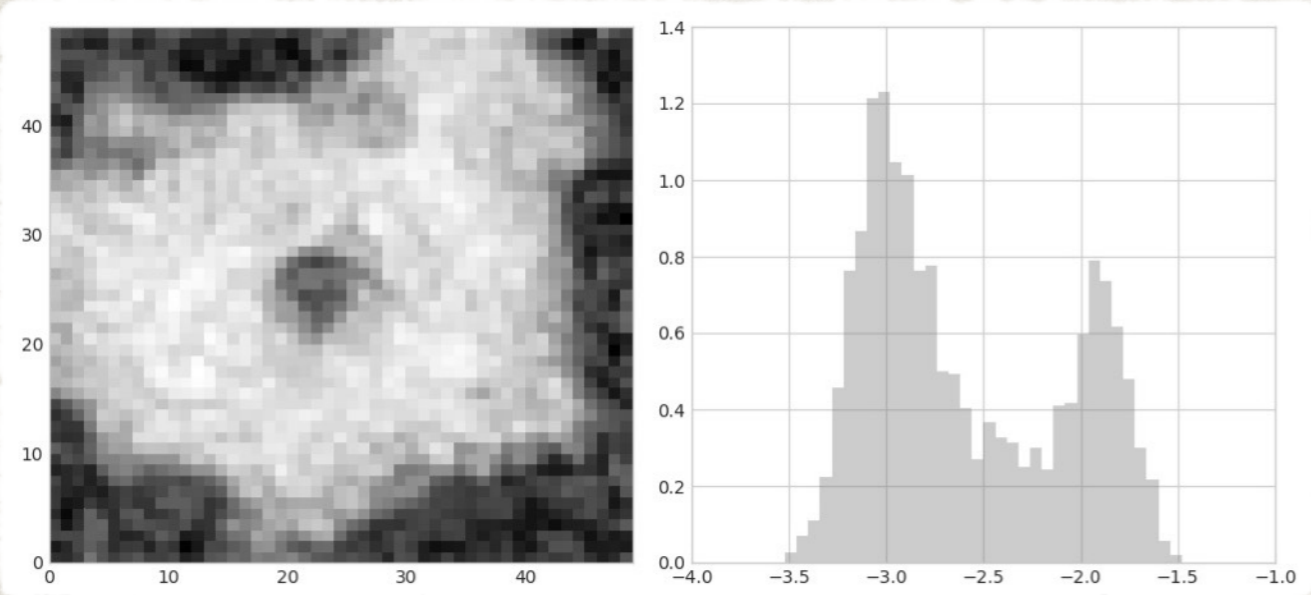
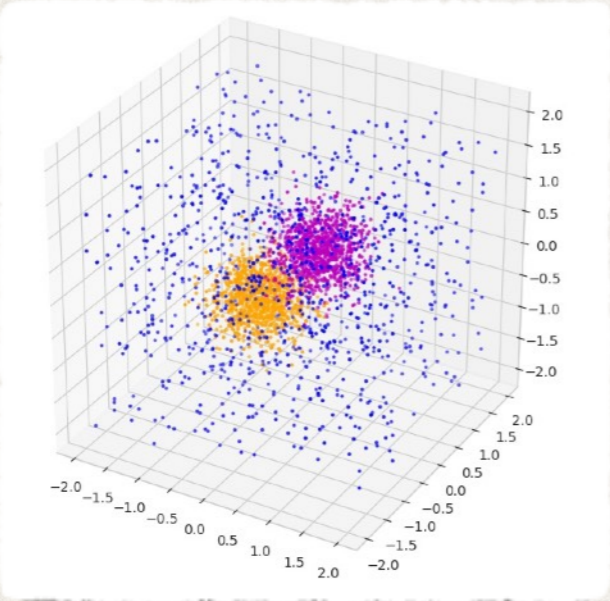
Preliminary Results

1. Identified 3 significant substructures in very metal-poor star catalog
2. Found an r-II star associated with one of the substructures

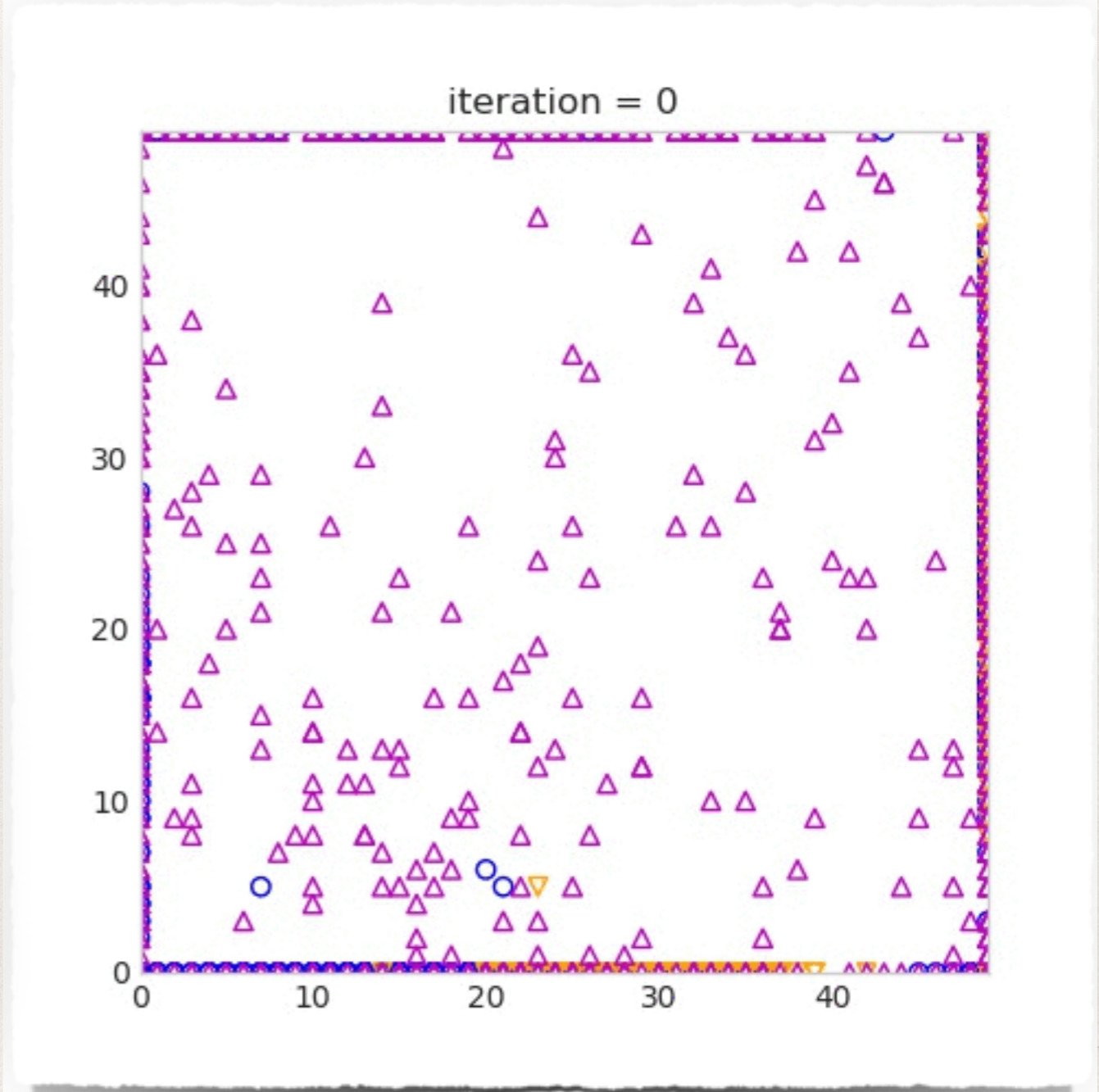
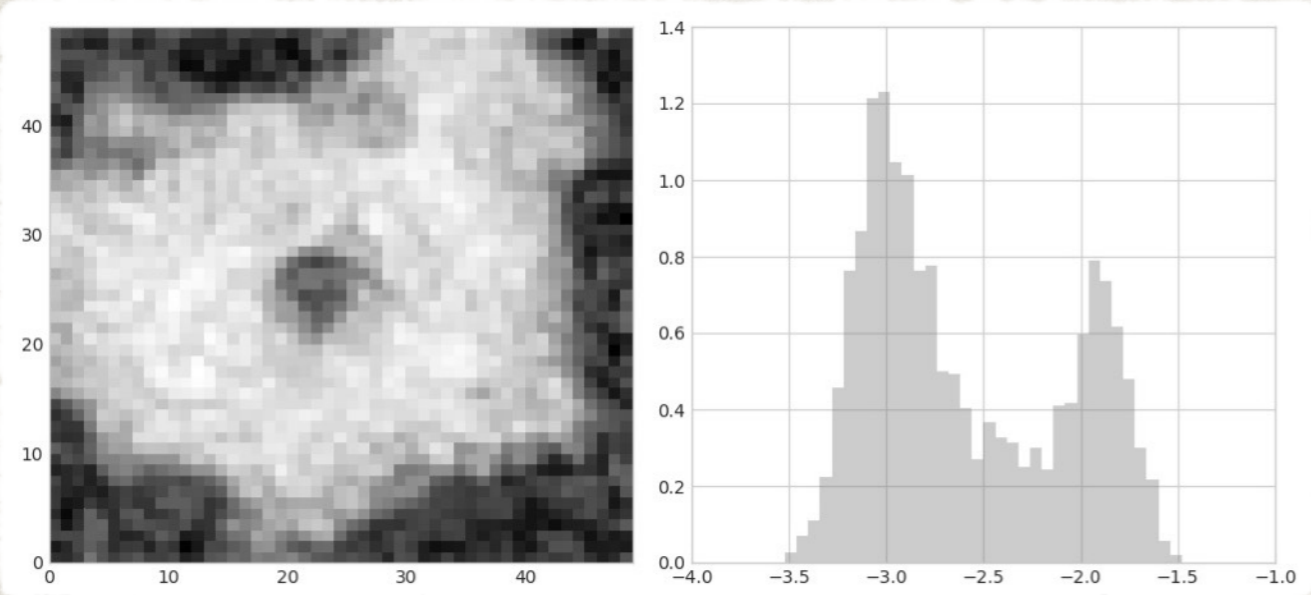
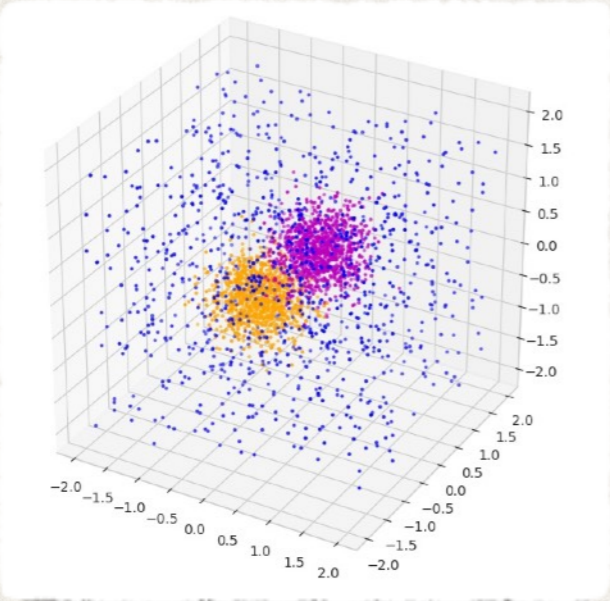


Method and Applications

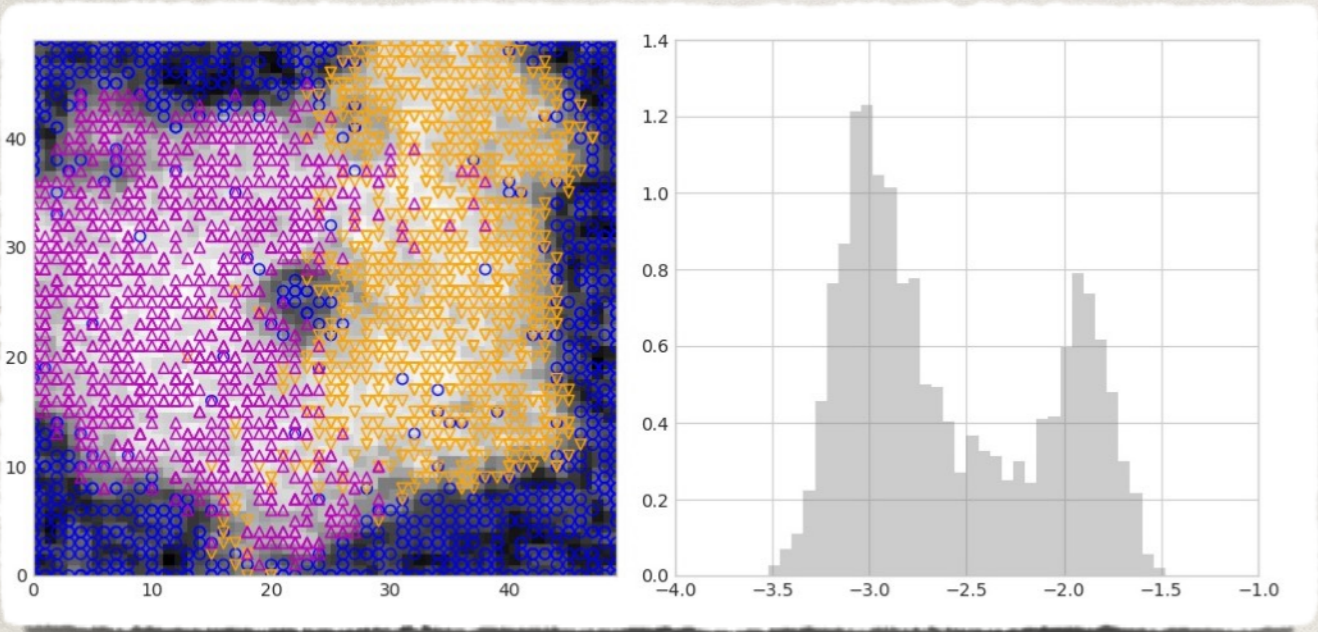
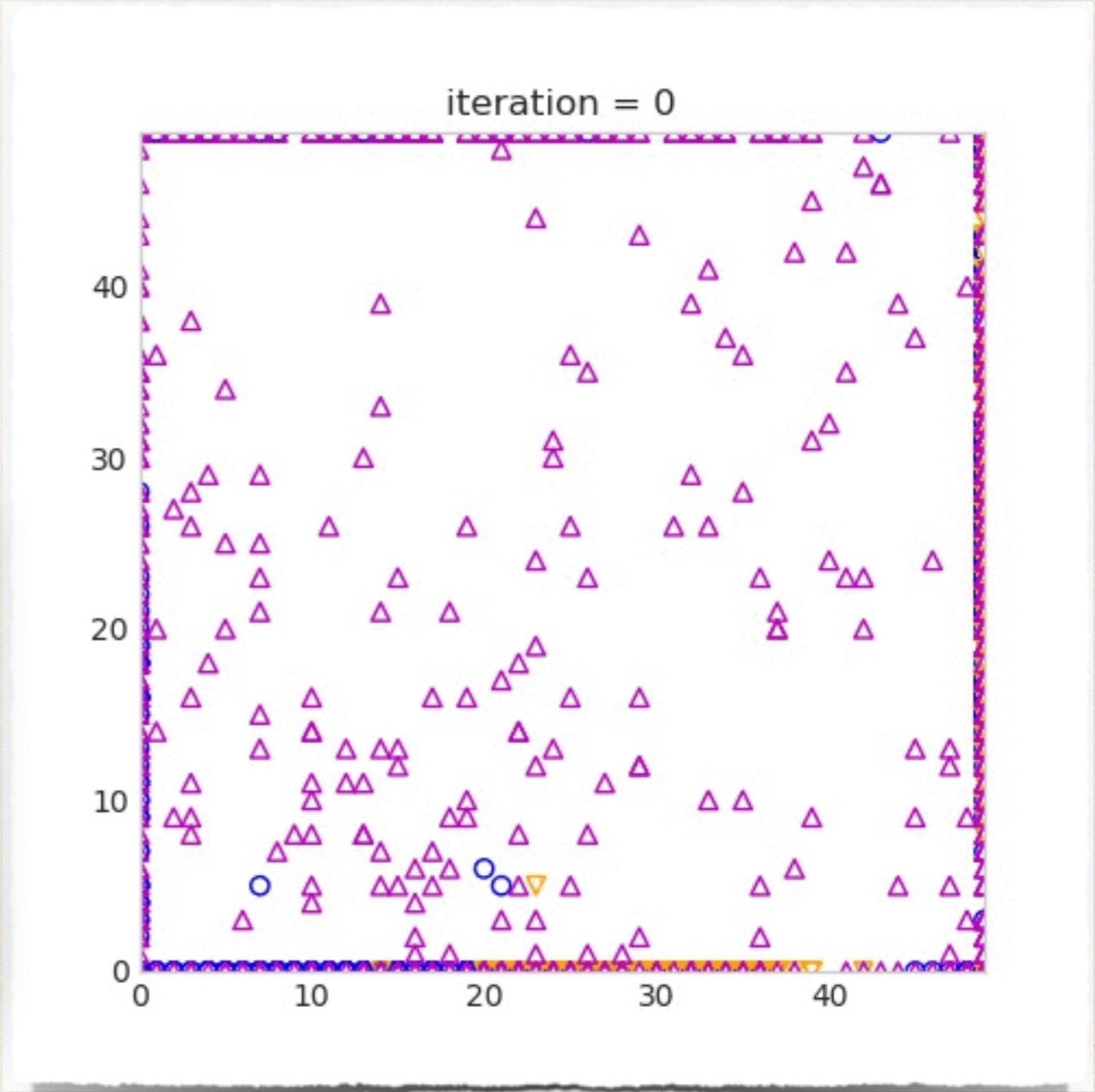
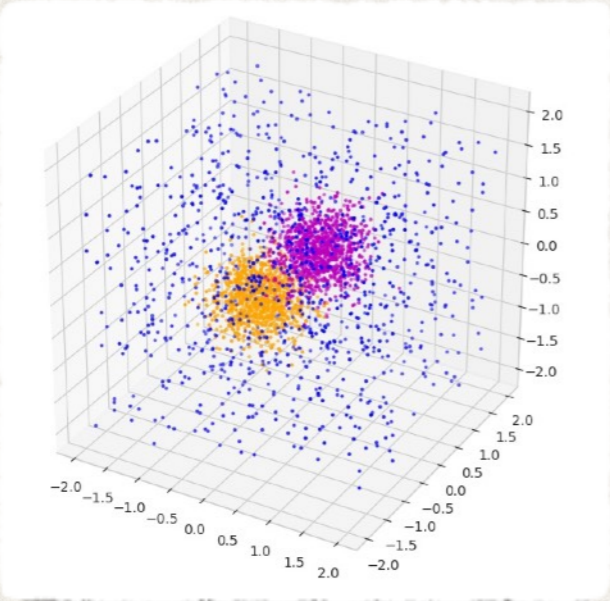
SELF-ORGANIZING-MAP (SOM)



SELF-ORGANIZING-MAP (SOM)



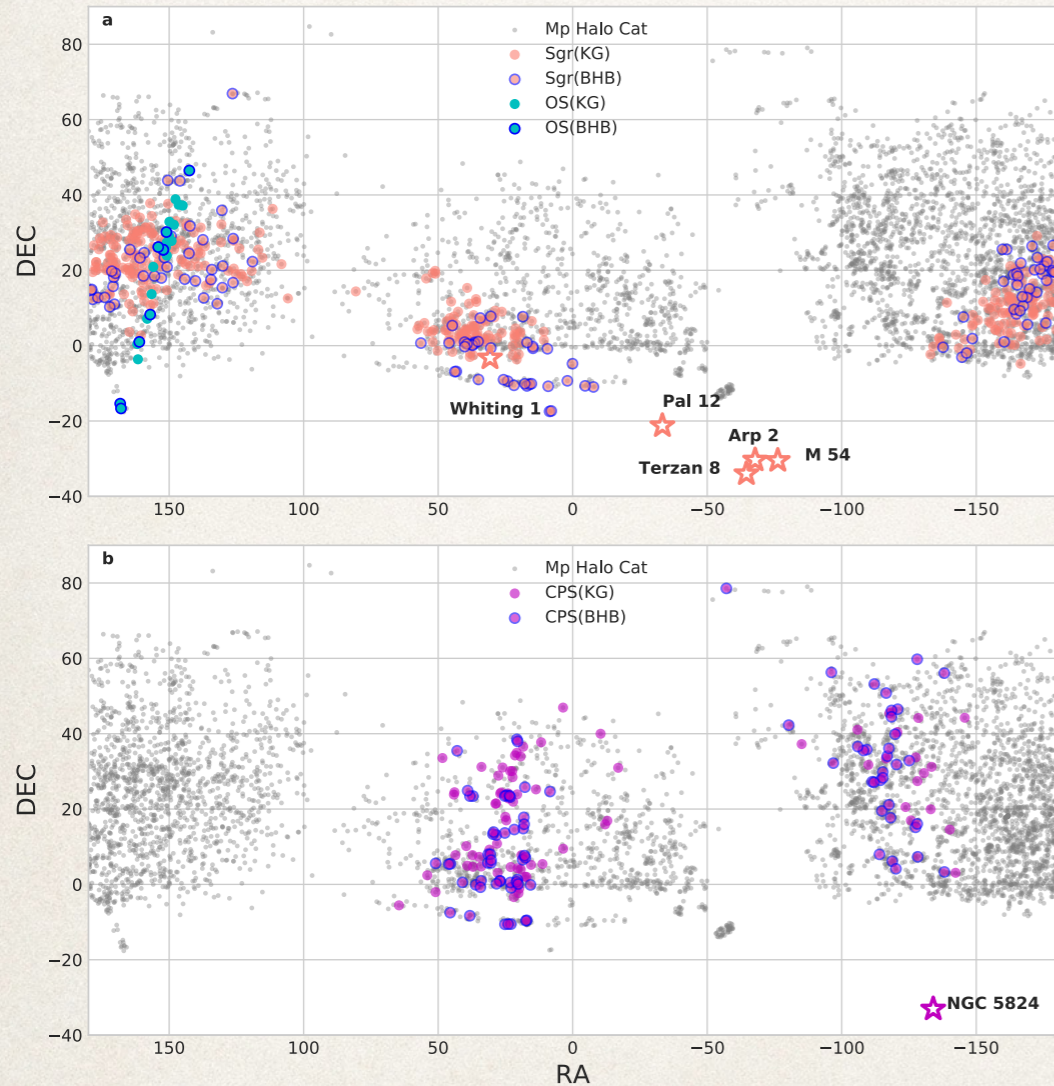
SELF-ORGANIZING-MAP (SOM)



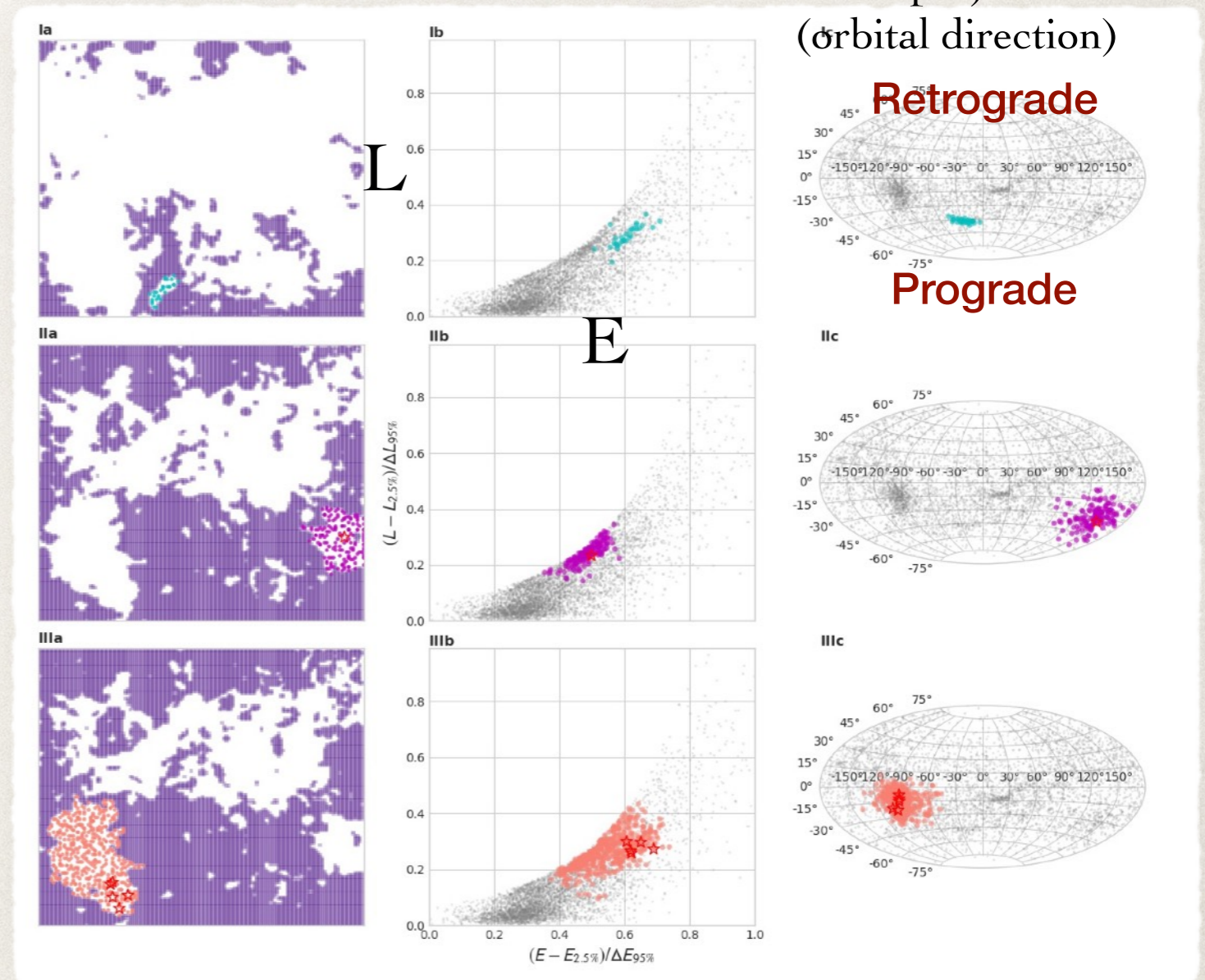
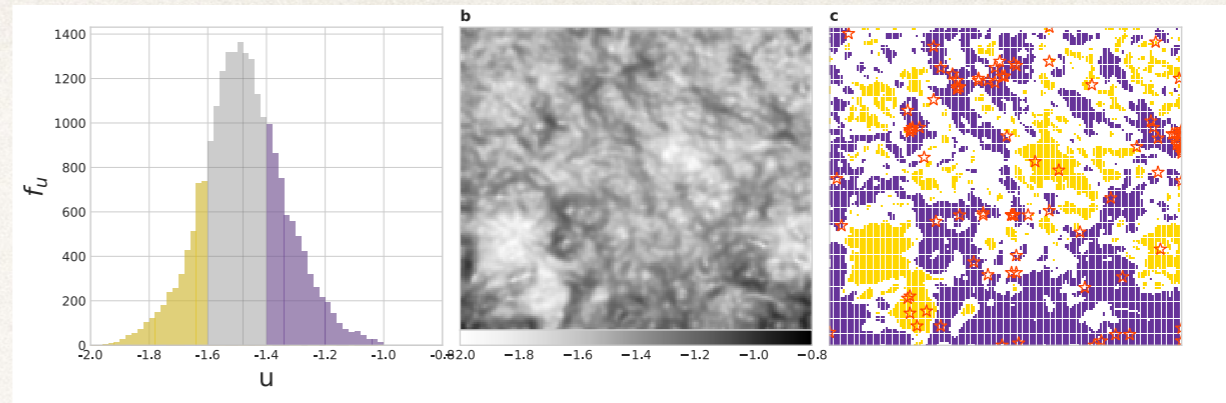
StarGO on the Outer Halo Catalog In the space of (E, L, theta, phi)

(LAMOST K-Giants + SEGUE BHBs)

1. Rediscover the Orphan, Sgr and its GCs
2. Discovery of the new component of the Cetus Stream
3. Confirm the association between Cetus and NGC 5824

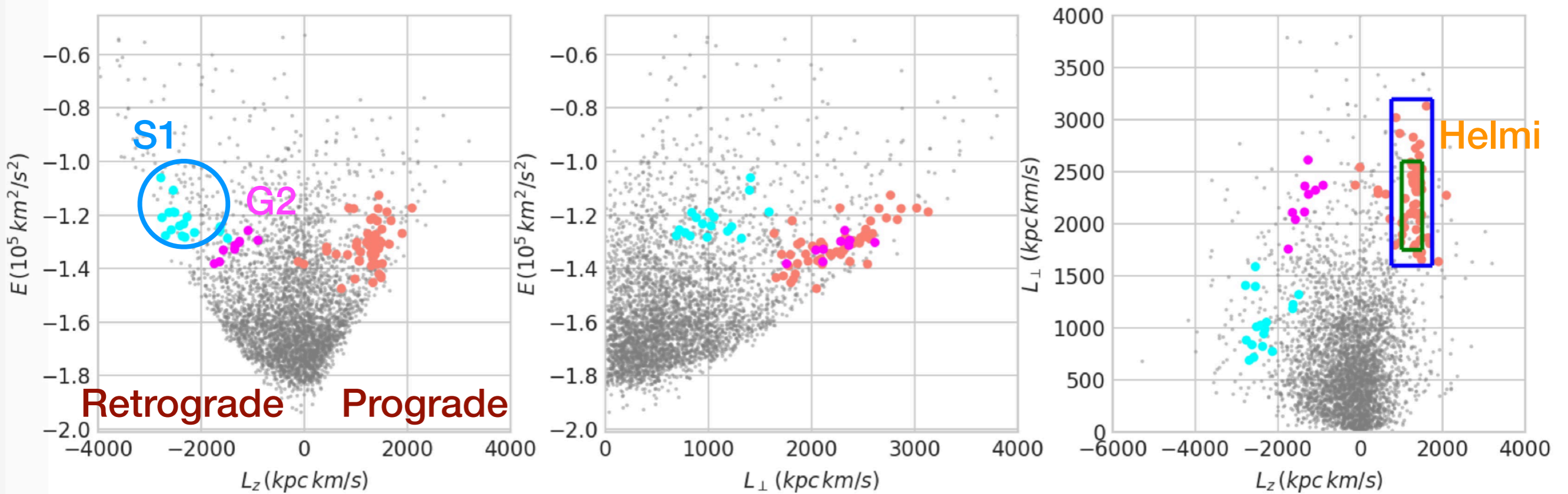
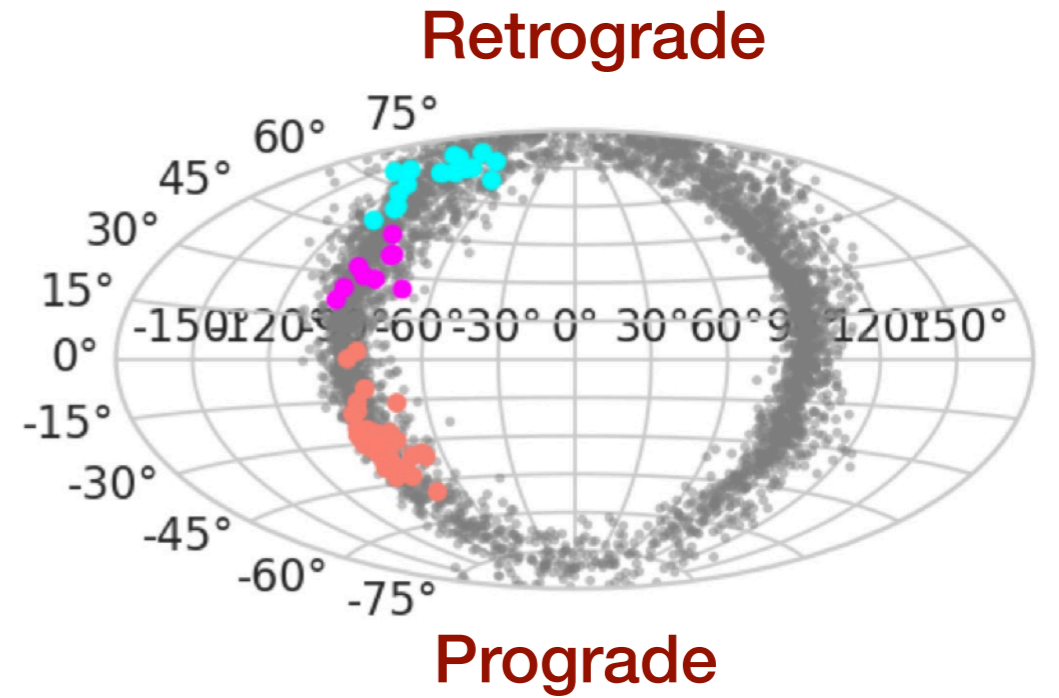
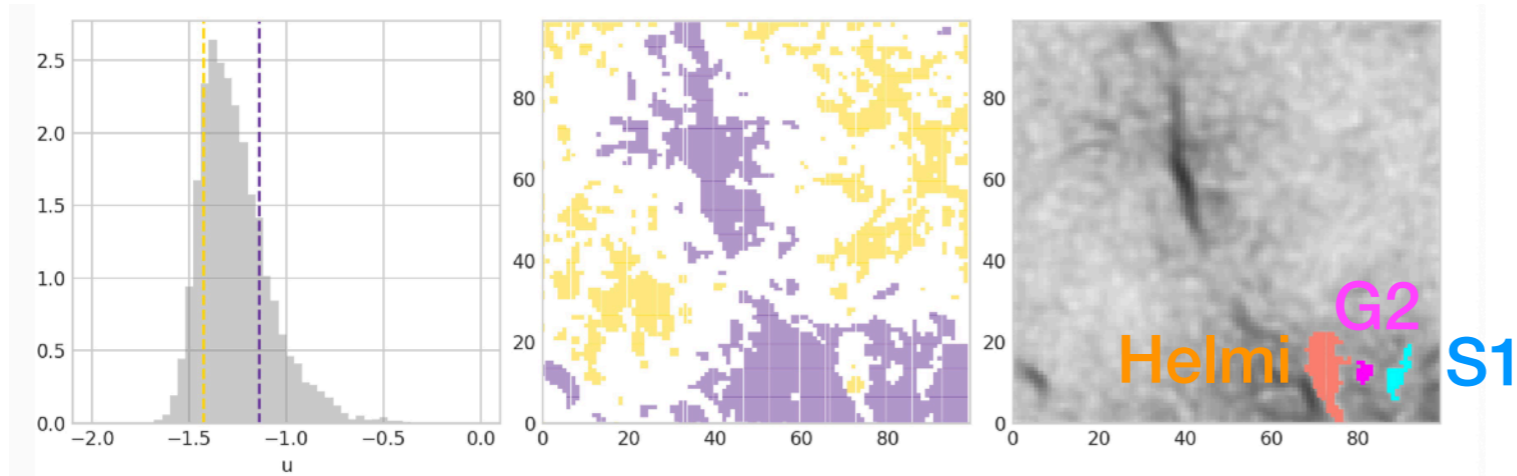


A easy tool to check the associations
between substructures & GCs



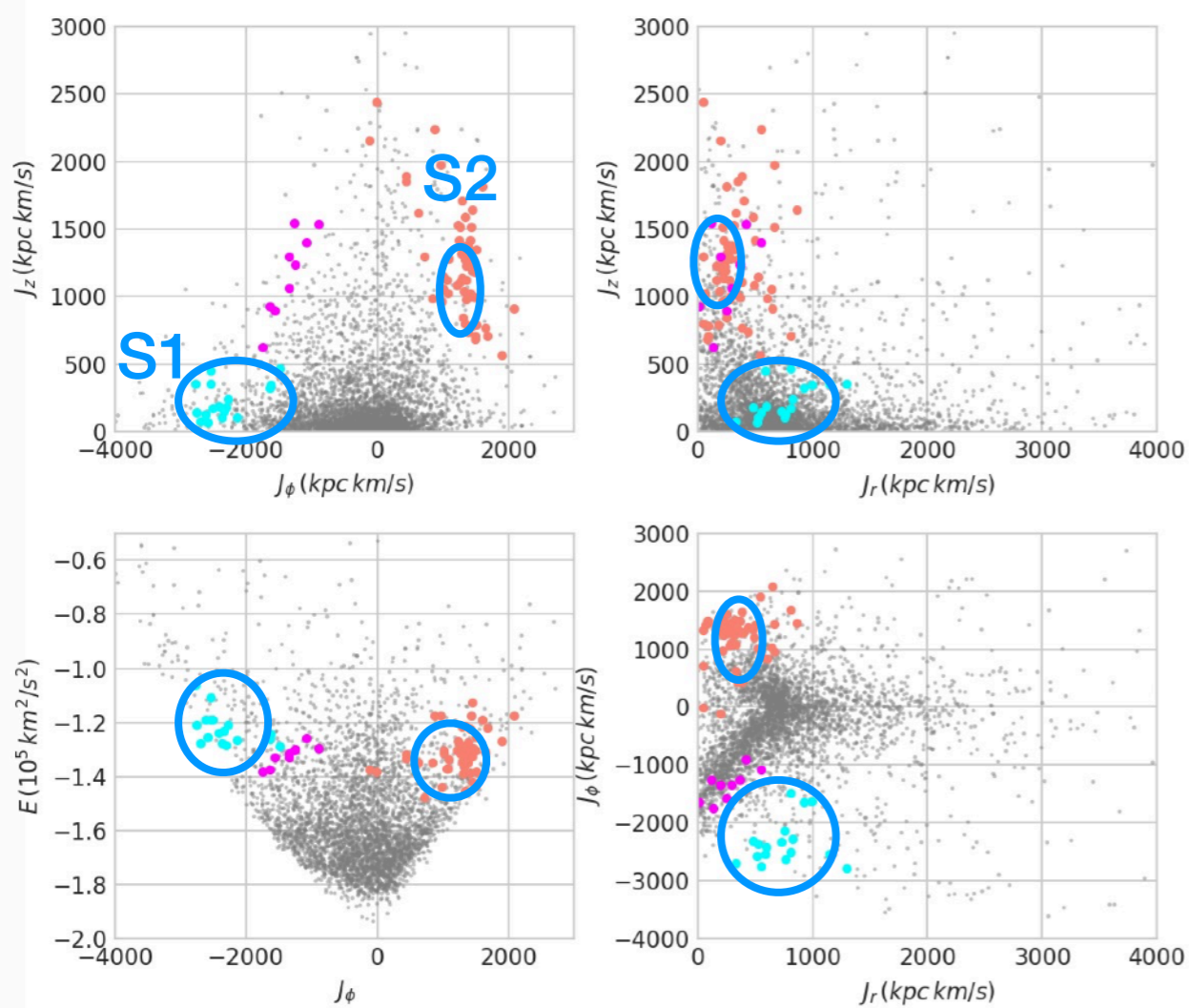
Back to the VMP Groups

StarGO on LAMOST VMP in the space of (E, L, theta, phi)



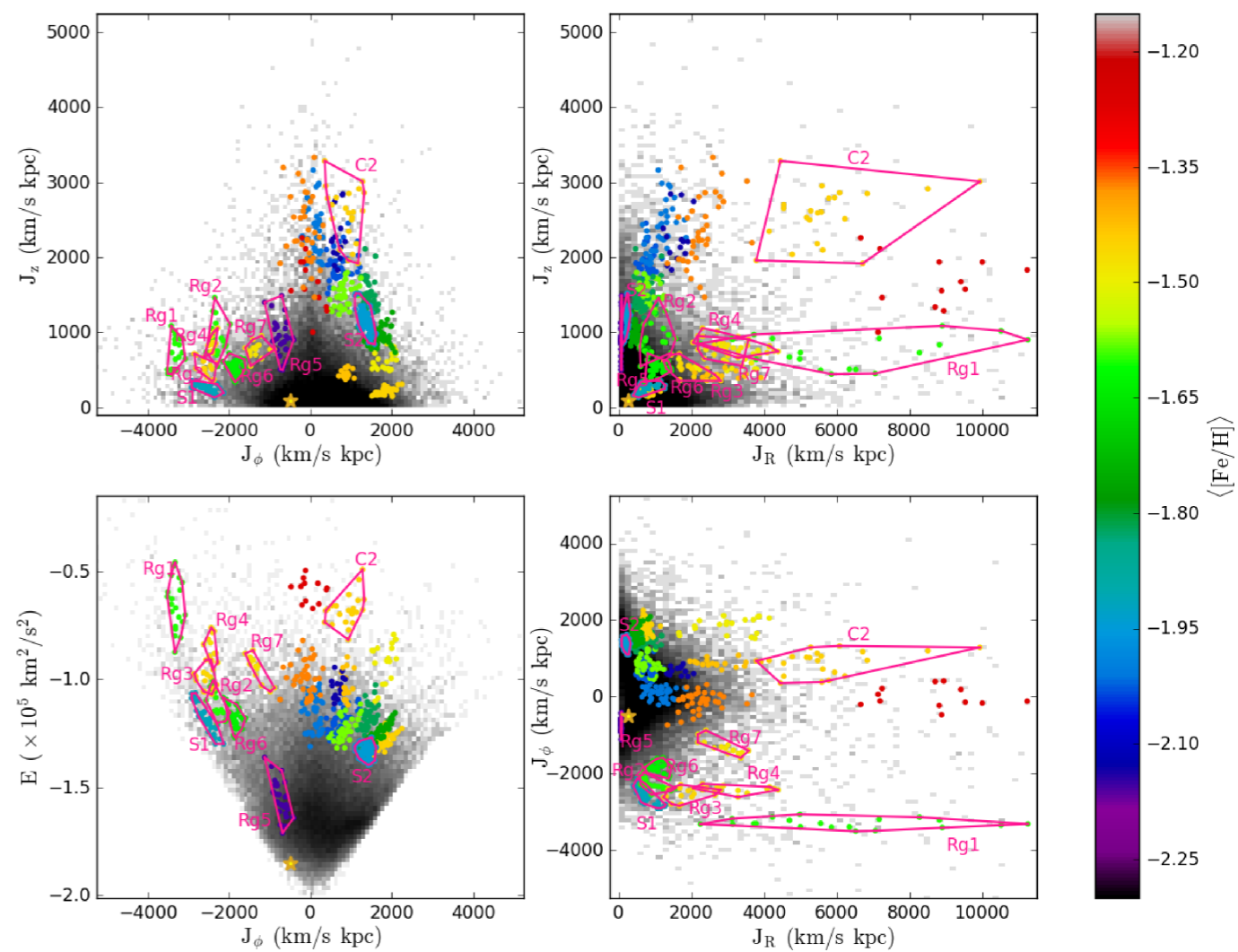
boxes from Koppelman & Helmi et al 2018

VMP Groups in Action Space

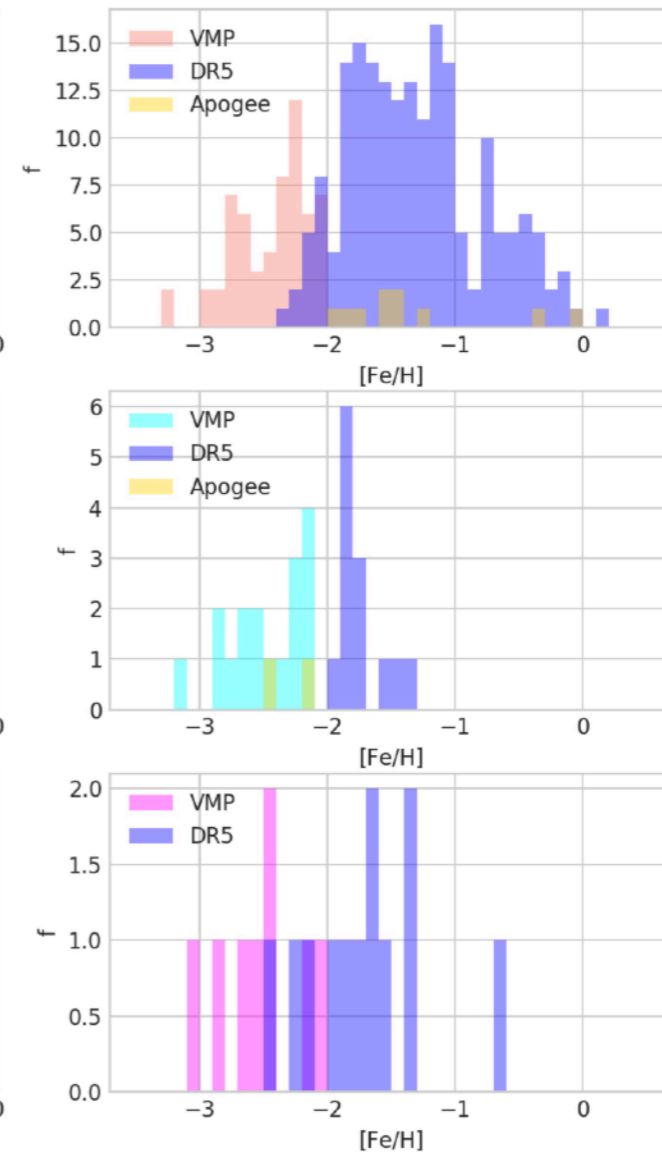
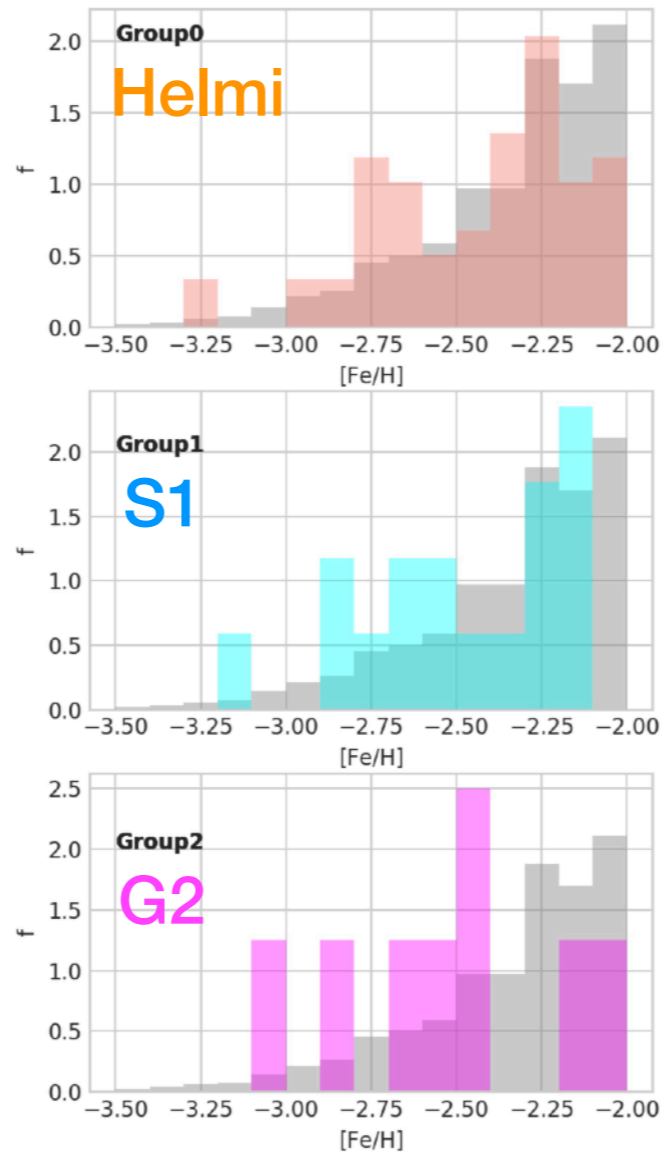
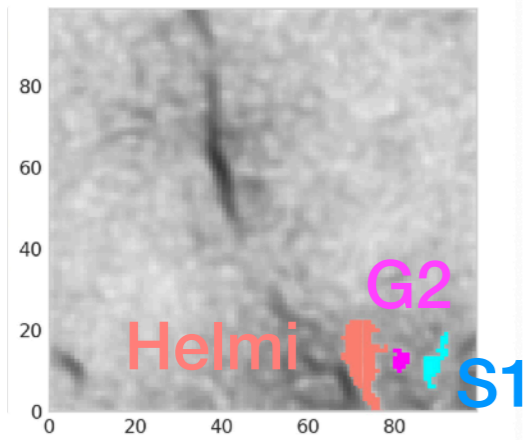


Groups Identified by Myeong et al 2018b In the Action Space

SDSSxGaia DR1



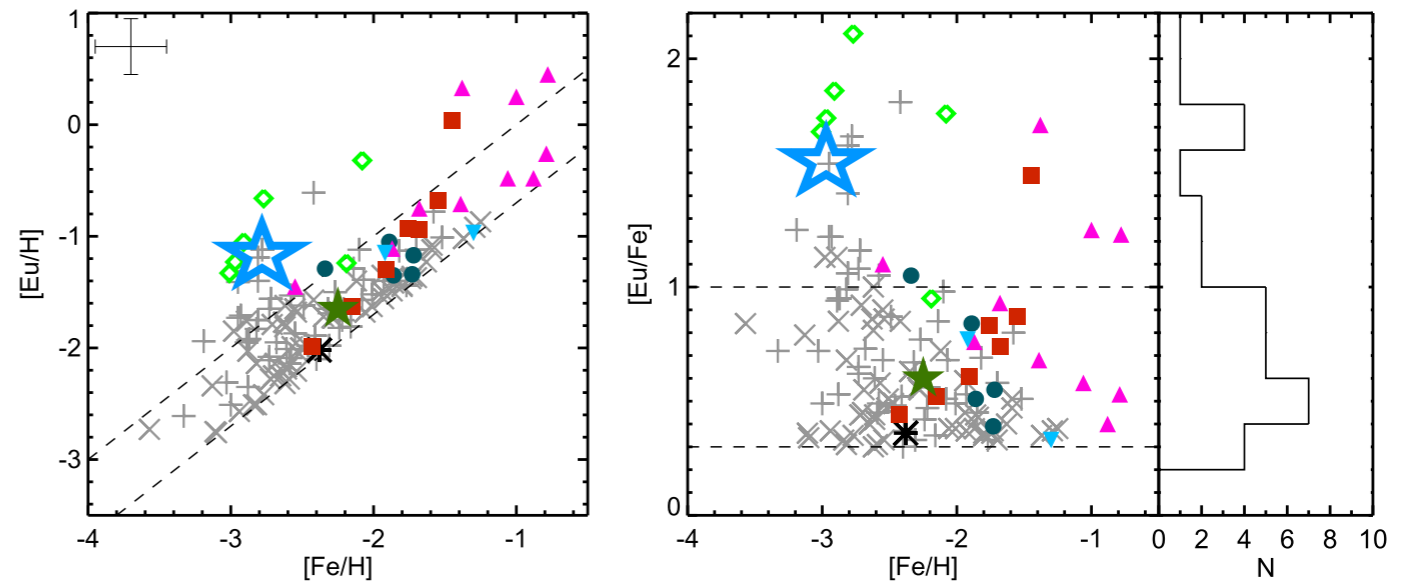
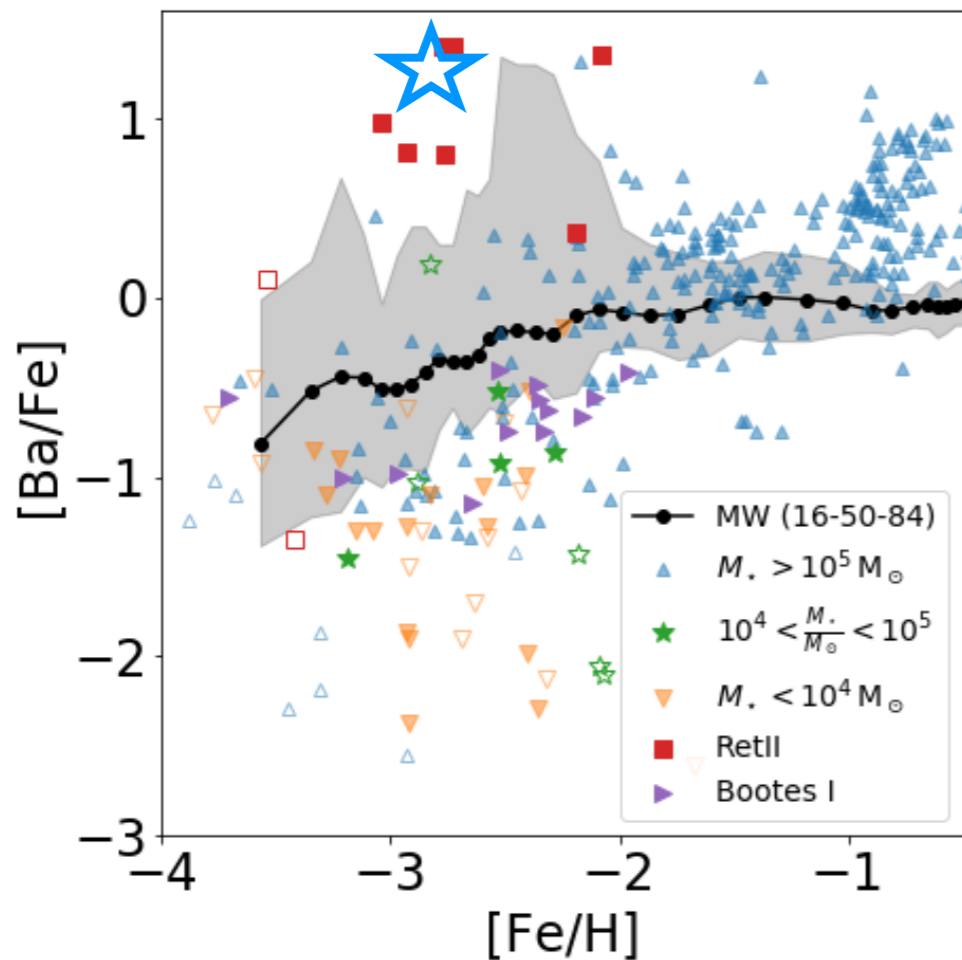
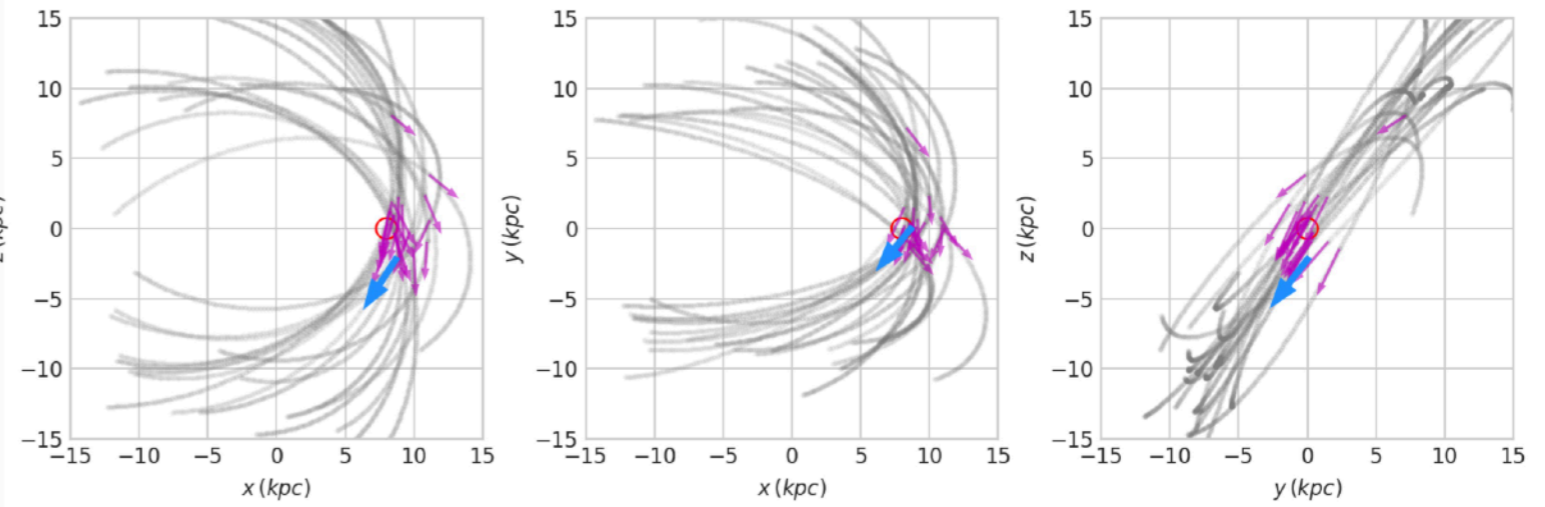
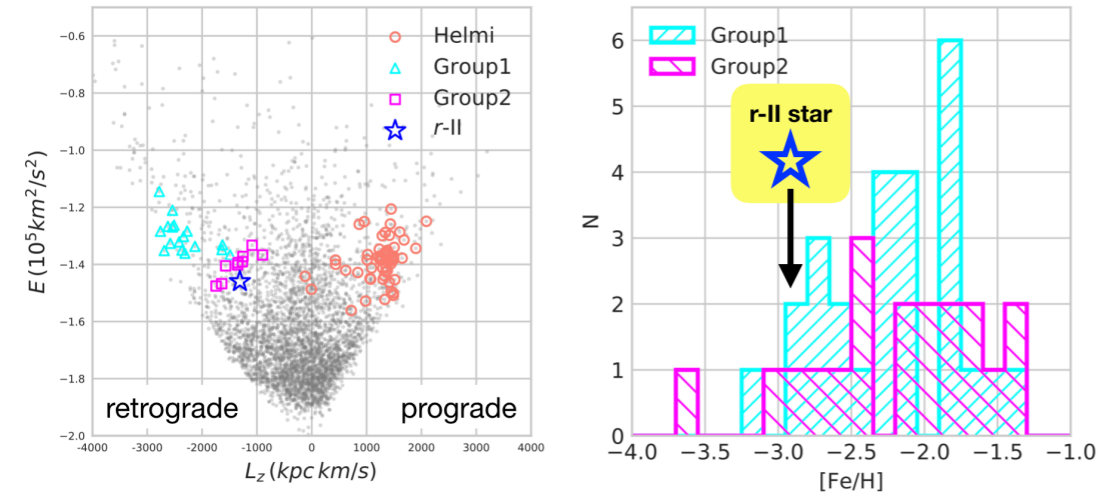
Searching members from LAMOST DR5, APOGEE, Gaia RVS, SAGA



1. Contamination from smooth halo background is $\sim 10\%$
2. Other mergers may contaminate more on the high metallicity end ($[Fe/H] \geq -2$)

Searching members from r-II star catalog (Roederer et al. 18)

G2 & r-II in galactic coordinates with velocity arrows



Hansen et al. 2017

Proposal made to get high resolution spectroscopy for G2 and S1 !

StarGO is useful for open cluster, stream, <https://github.com/salamander14/StarGO> substructure finding

Plot made by Tadafumi Matsuno