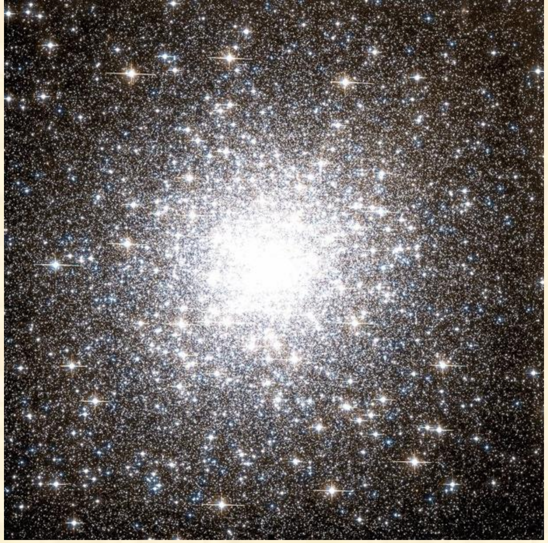

Outer Regions of Globular Clusters with WEAVE

Week of Weave 2019

Barcelona

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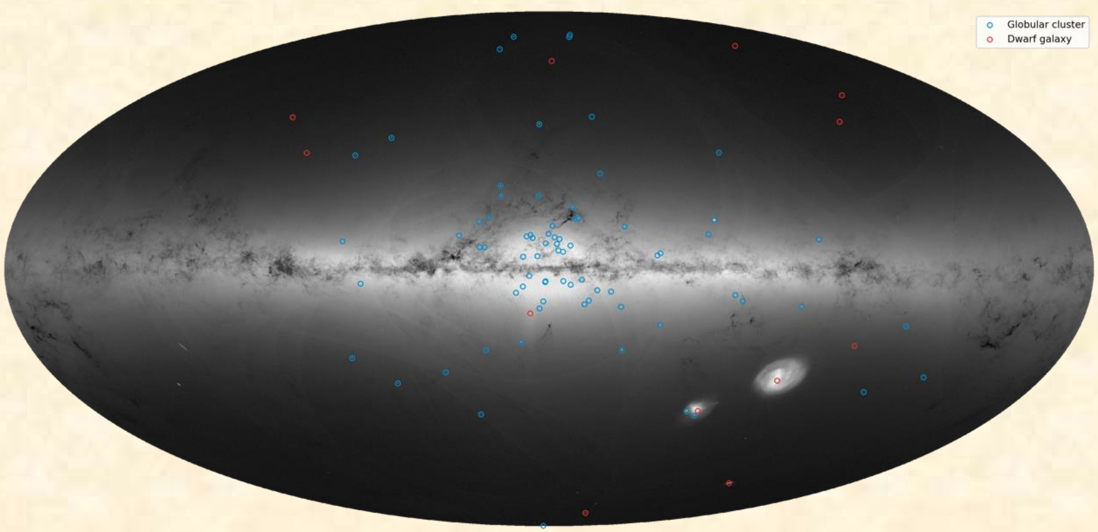
University of Edinburgh

Globular Clusters in the Milky Way

- 160+ Globular Clusters in the Milky Way
- Each cluster is unique, possessing different stellar populations, metallicities, and are all quite old.
- Beyond 1 half-light radius for GCs has thus far been poorly-explored but these regions are growing increasingly intriguing.

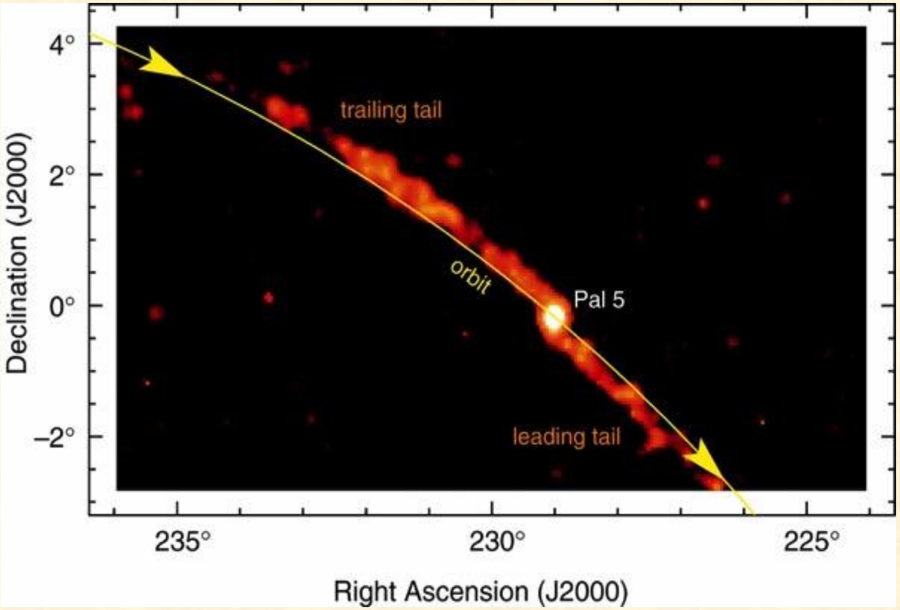


Helmi et al. 2018

Extended Structures of GCs

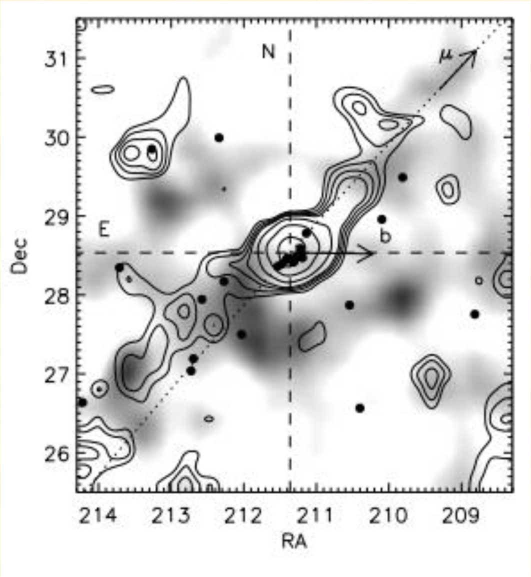
Large tidal structures can emanate out of the cluster center formed entirely of escaping stars.

Palomar 5:



Odenkirchen et al. 2001

NGC 5466:

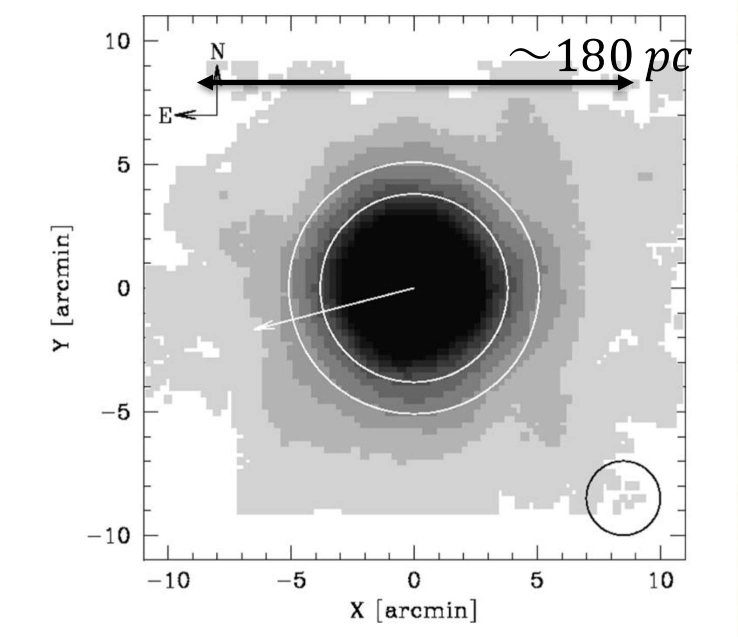


Belokurov et al. 2007

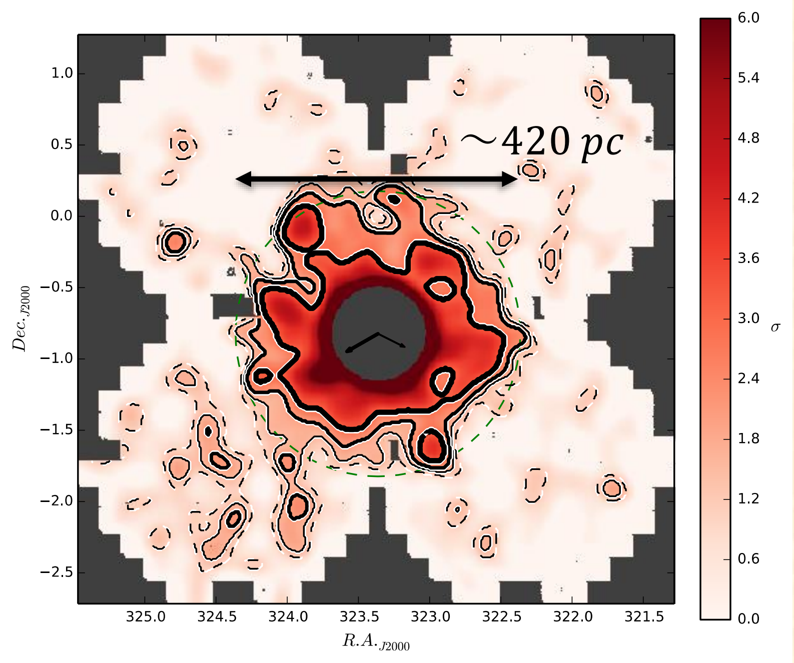
Extended Structures of GCs

Some larger clusters have large diffuse spherical envelopes, whose origin is not currently well understood.

NGC 5694



NGC 7089



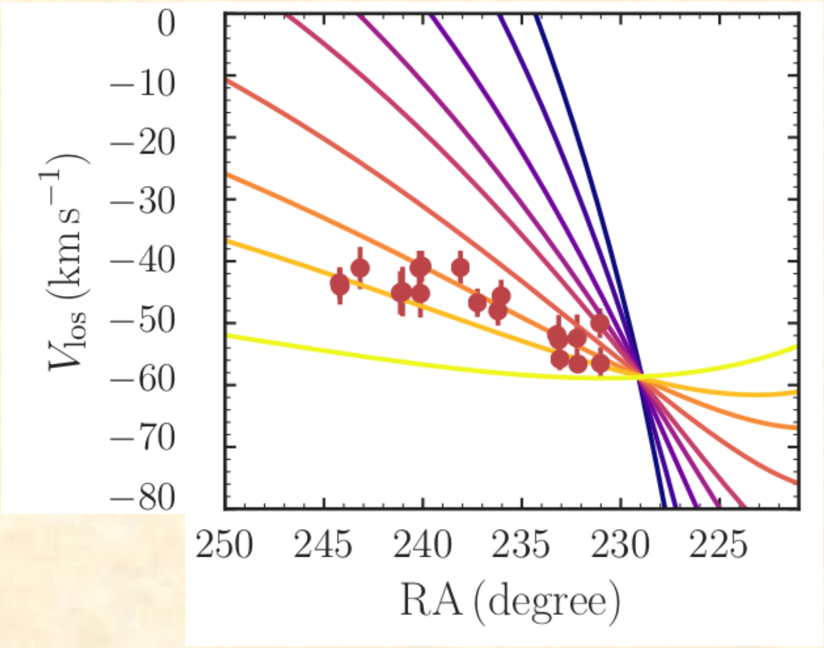
Correnti et al. 2011

Kuzma et al. 2016

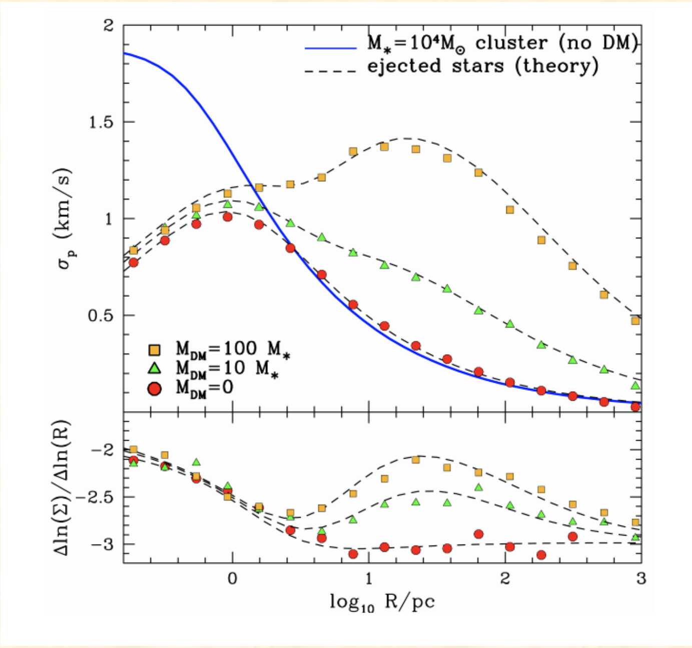
Extended Structures of GCs

Qualitative measurements of these features can have a multitude of benefits on different fields.

Radial velocities along tidal tails help constrain the shape and mass of the halo (Bovy et al. 2016).

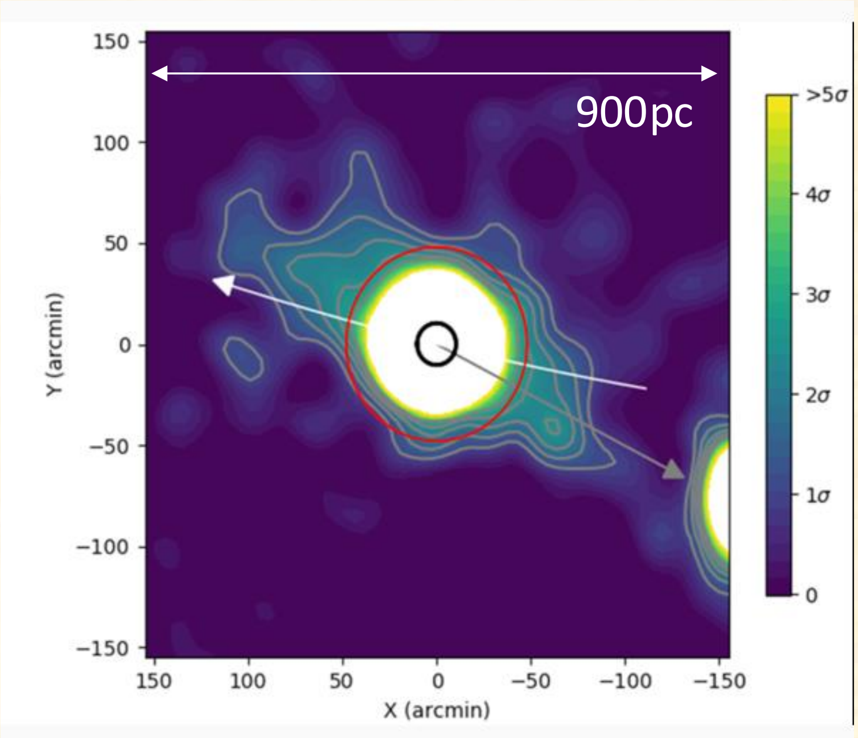


Velocity dispersion of a stellar envelope infer the existence of dark matter halos around GCs (Penarrubia et al. 2017).

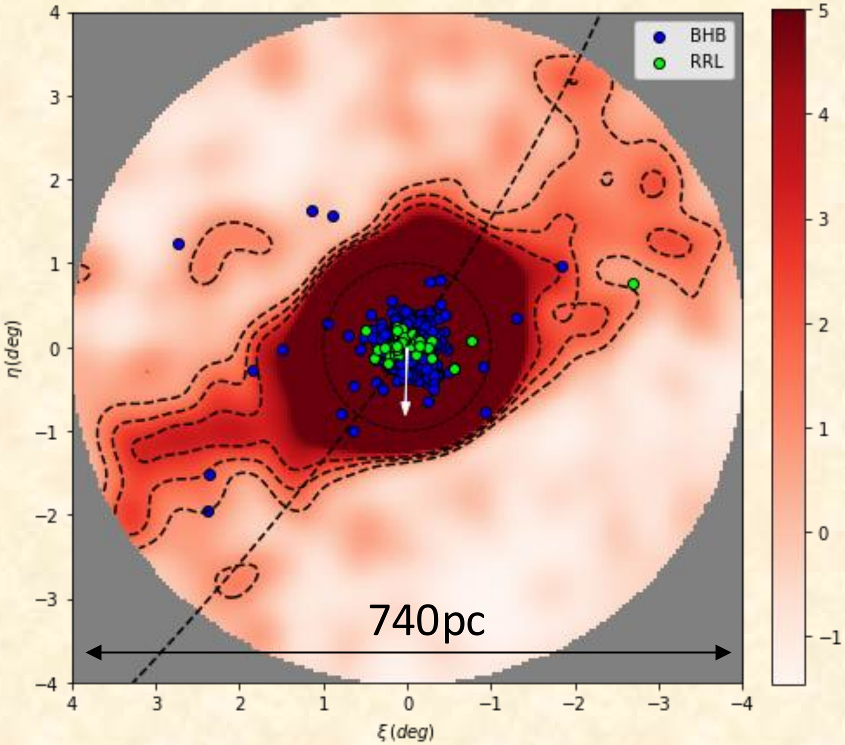


GC outskirts with Gaia

Gaia is greatly facilitating the quantitative study of GC outskirts through providing precision photometry and astrometry.



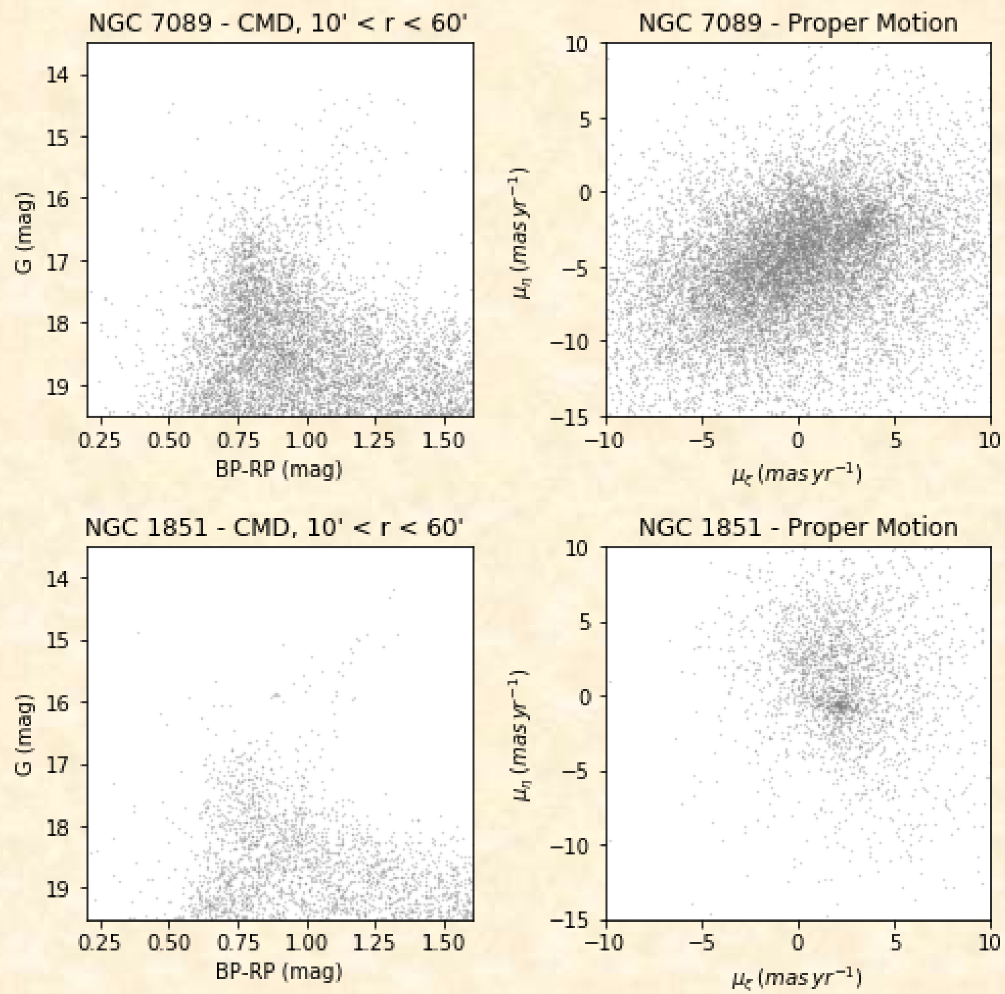
NGC 362, Carballo-bello 2019



NGC 5139, Kuzma et al. In prep

GC outskirts with Gaia

Mixture model techniques can detect potential GC member stars amongst the field in proper motion and colour-magnitude space.



GC outskirts with Gaia

Gaia catalog first undergo a photometric selection.

Proper motions modelled as 2D-Gaussians.

Spatial distributions are different for each component:

- King (1962) model for the cluster.
- Linear gradient model for the foreground.
- Quadrupole model for the extended component.

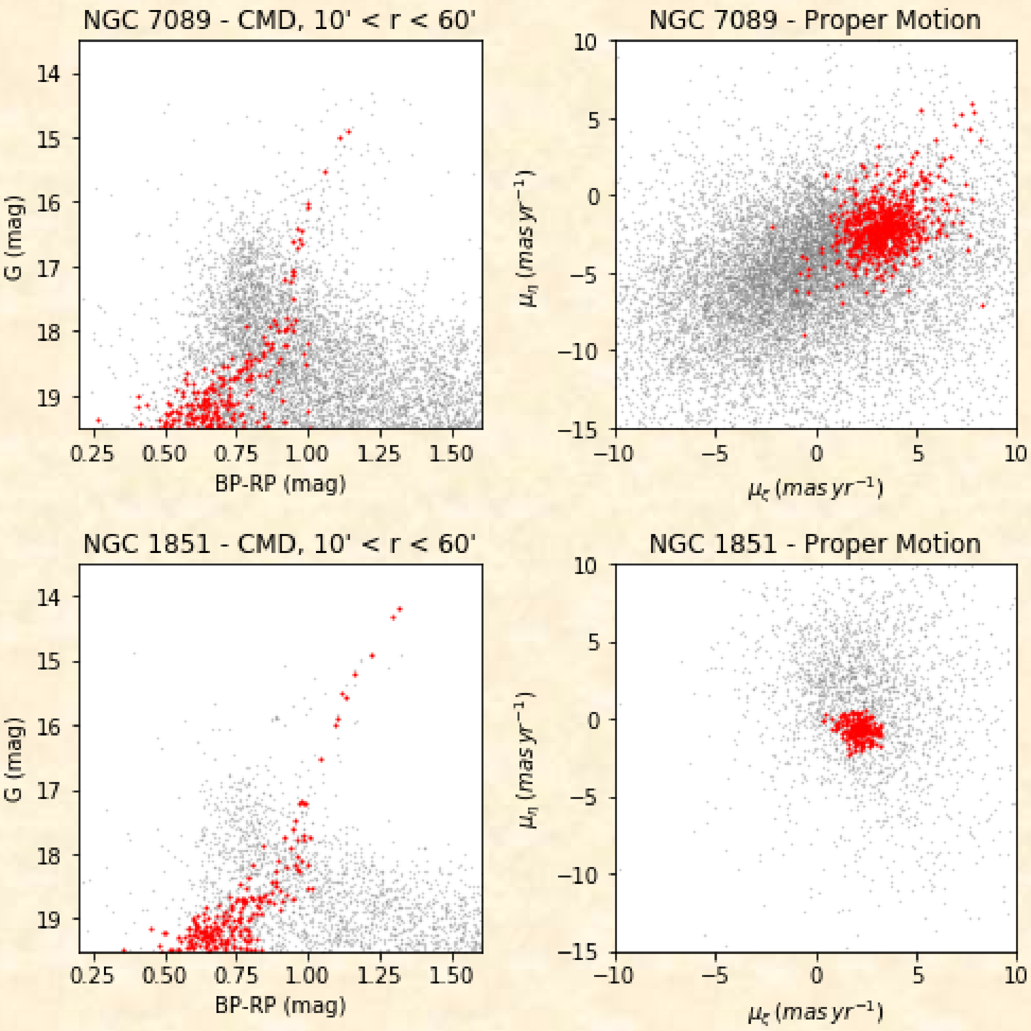
Stars are assigned a probability that the belong to the cluster + extended component:

$$P = \frac{f_{cl}\left((1 - f_{ex})\mathcal{L}_{cl} + f_{ex}\mathcal{L}_{ex}\right)}{\mathcal{L}_{tot}}$$

Extended Structures in Gaia

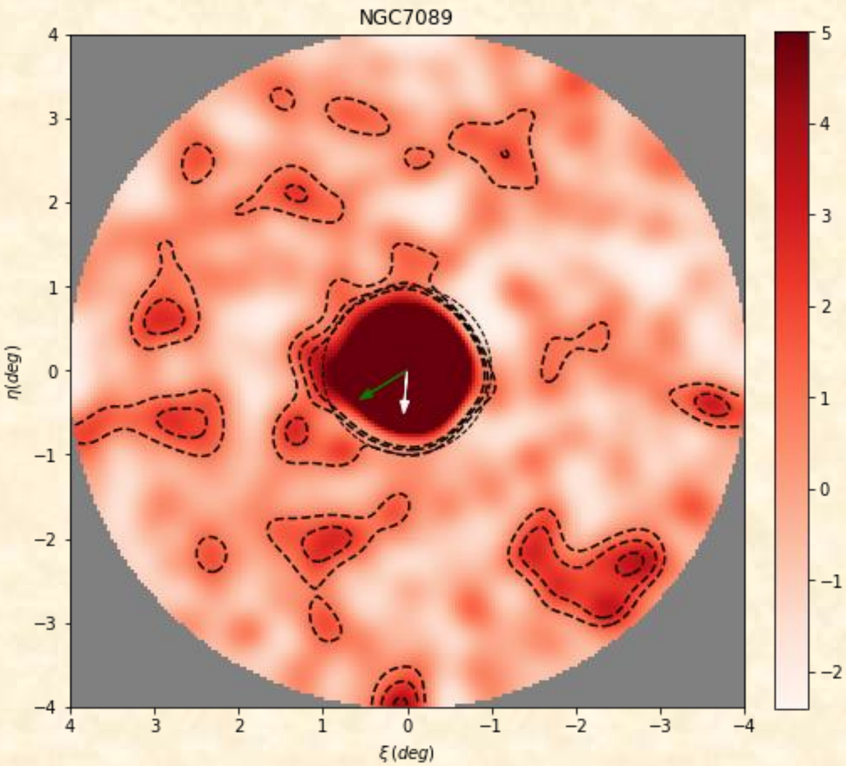
Same plots as before, but over plotted in red are all stars with membership probability of 0.3 or more.

Our technique provides a cleaner selection of stars, ideal for spectroscopic observations with WEAVE.

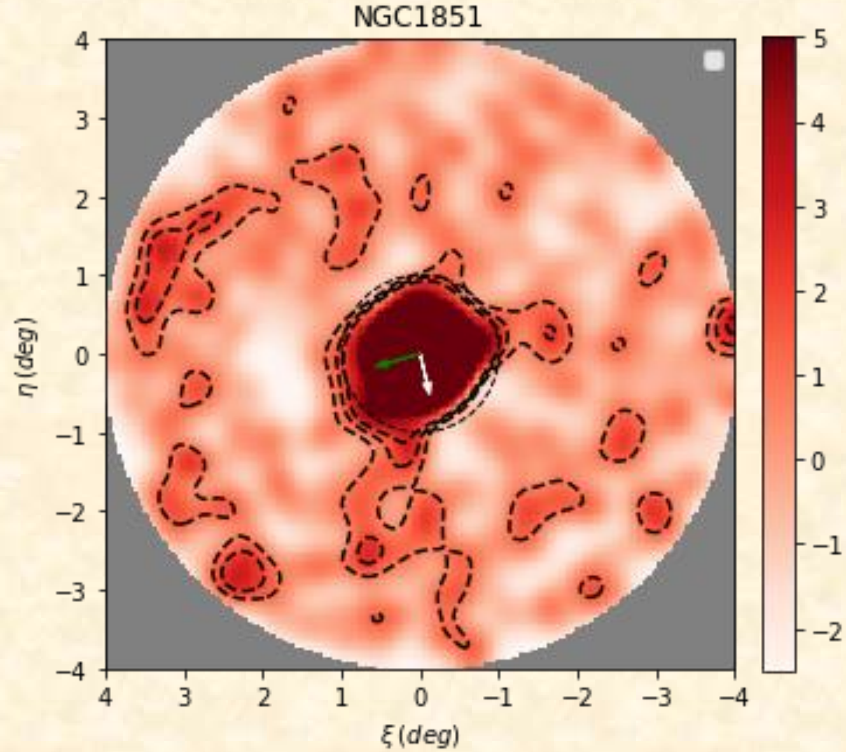


Extended Structures in Gaia

2-D surface density profiles of NGC 7089 and NGC 1851. The envelopes are recovered and similar in size to Kuzma et al. (2016, 2018).



Inner ring radius is 1 deg = 200 pc



Inner ring radius is 1 deg = 210 pc

GC Peripheries with WEAVE

Outer peripheries of GCs can be explored efficiently for the first time with WEAVE.

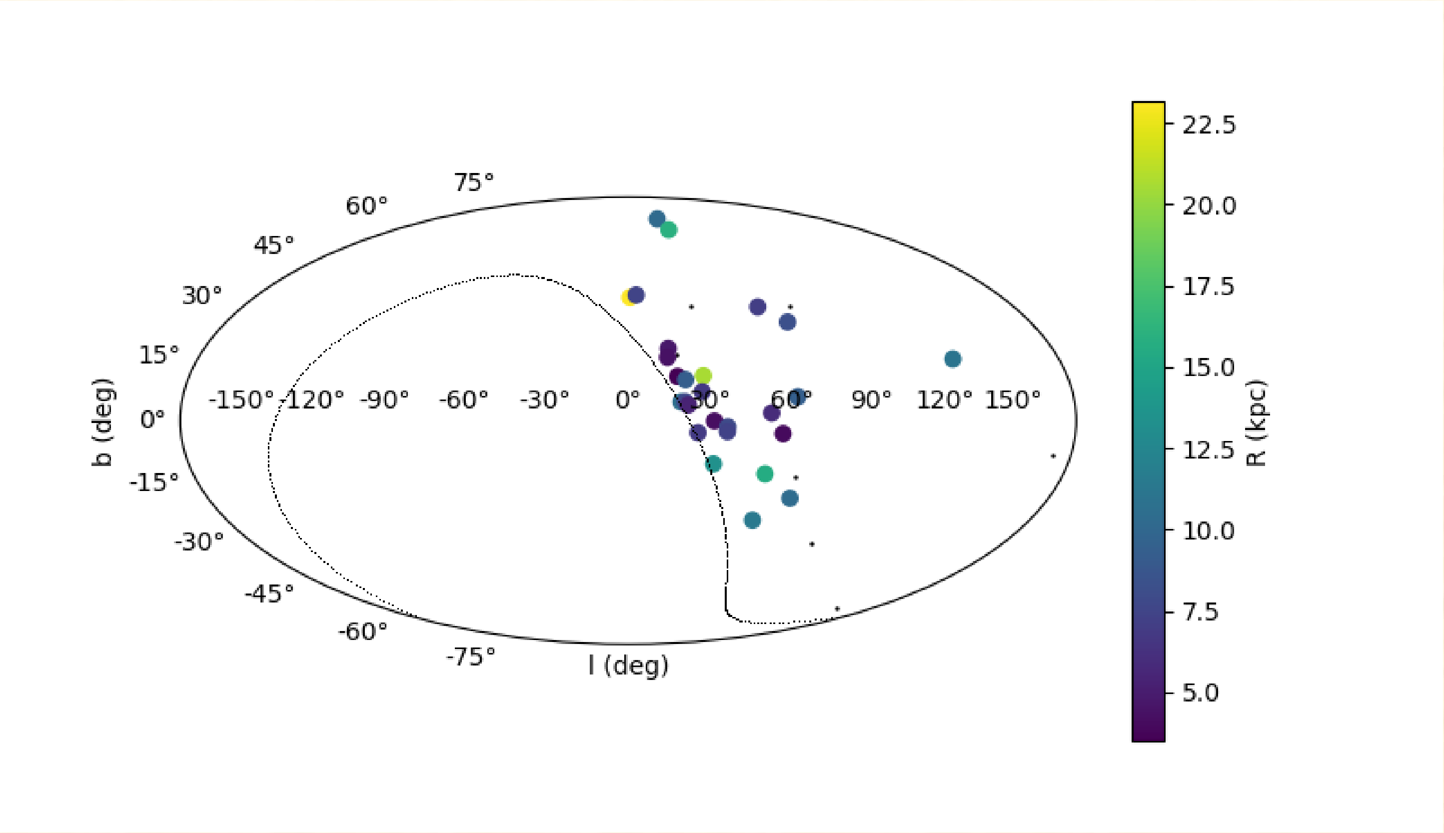
WEAVE can achieve:

- Radial velocities and Ca II metallicities.
- Chemical tagging for the brighter stars in the outer regions (e.g., CN, CH)

The turn-off and the top of main sequence will be V ≈ 19-20 mag (approx. 25 kpc).

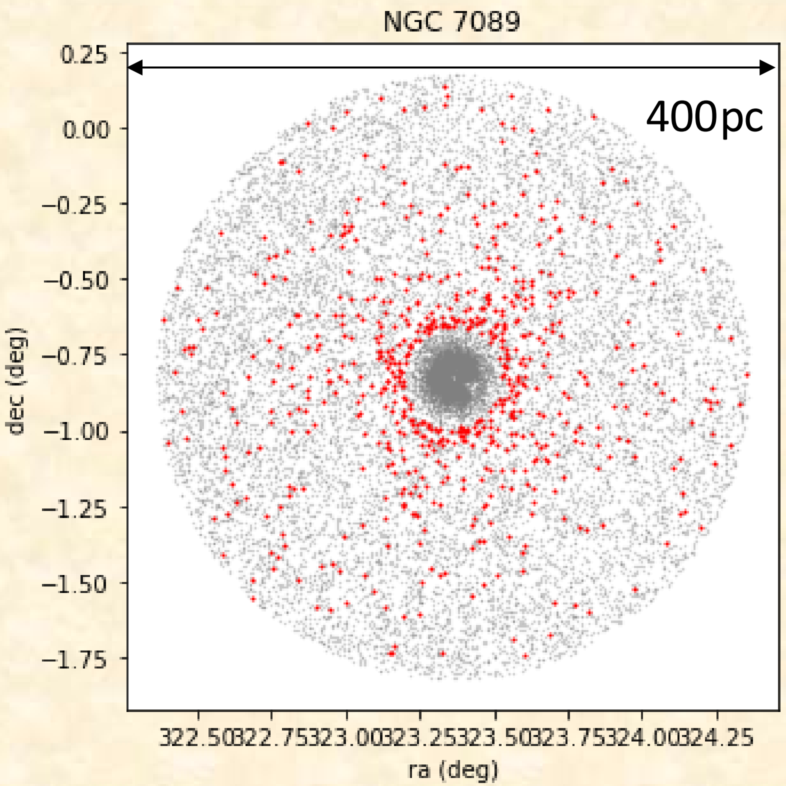
GC Peripheries with WEAVE

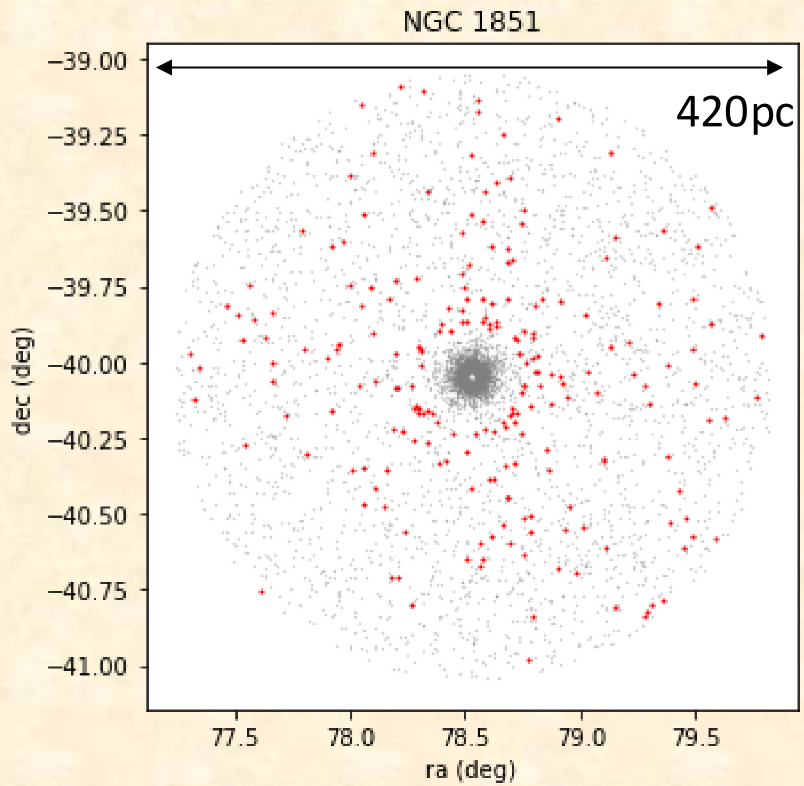
Galactic coordinate projection of the MW GCs in the WEAVE footprint (dec > -10°). 32 GC targets out to 25 kpc.



GC Peripheries with WEAVE

Target density is suitable for WEAVE:
- Crowding not an issue like in the inner regions of GCs (e.g., M2 = 600 targets, NGC1851 = 250 targets, averaging 0.02 – 0.05 stars per square arcmin).
- Complementary with a study of the inner regions of GCs with WEAVE.





GC Peripheries with WEAVE

Exposure examples based on the WEAVE ETC:

	NGC 7089 ($R_\odot$=11.5 kpc)	**NGC 1851 ($R_\odot$=12.1 kpc)**	**Palomar 5 ($R_\odot$=23.2 kpc)**
Horizontal Branch mag	V = 16.05 mag	V = 16.09 mag	V = 17.51 mag
S/N at exposure 1080s LR red (HR red)	S/N_A = 78 (74) S/N_{pix} = 50 (23)	S/N_A = 76 (72) S/N_{pix} = 50 (22)	S/N_A = 76 (No HR) S/N_{pix} = 50 (No HR)
Turn-off Base mag	V ≈ 19 mag	V ≈ 19 mag	V ≈ 20 mag
S/N at exposure 1080s LR red	S/N_A = 18 (No HR) S/N_{pix} = 2 (No HR)	S/N_A = 18 (No HR) S/N_{pix} = 12 (No HR)	S/N_A = 10 (No HR) S/N_{pix} = 6(No HR)
Exposure time required for S/N_pix = 10 with LR red	~ 1300s	~ 1080s	~ 2300s

S/N_A= signal to noise per Angstrom, S/N_{pix} = signal to noise per pixel

GC Peripheries with WEAVE

Should this be considered as part of the main survey?

Potential issues:

- Target availability/feasibility? *Field main sequence and turn off targets are high priority, but GC main sequence and turn off targets are important for this project. However, potentially will need longer exposures to get achieve more accurate velocities for membership determination.*

- Field selection as part of the main survey? *GCs not necessarily targeted in the main survey, therefore only part of the periphery will be observed if a GC is part of an observed field, limiting target selection further.*

Summary

- We have developed a mixture model technique to identify highly-probable GC members at large cluster-centric radii.
- Demonstrated how WEAVE can effectively explore these regions that are currently not well understood.
- Could be observed as part of the main survey but incomplete field coverage, low S/N at the turn-off and main could be problematic.
- Might be more effective as part of a community-driven survey.