Extended Globular Cluster Structure in Gaia

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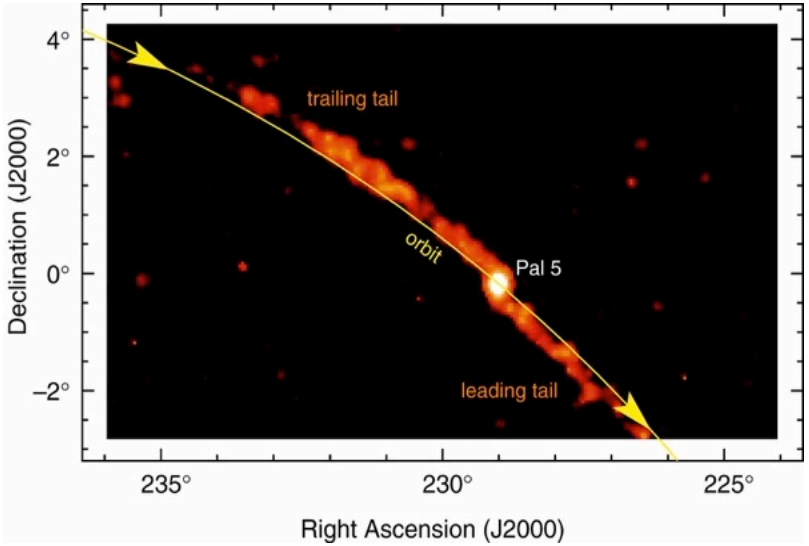
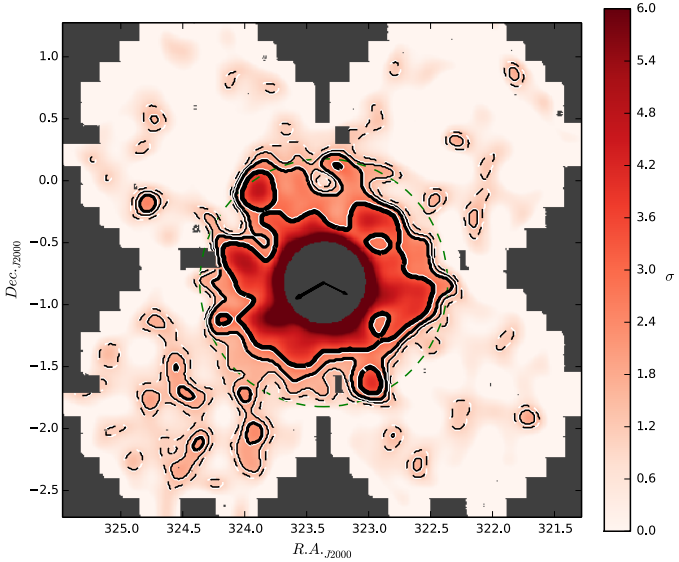
Defining "Extended Structures"

Tidal tails:



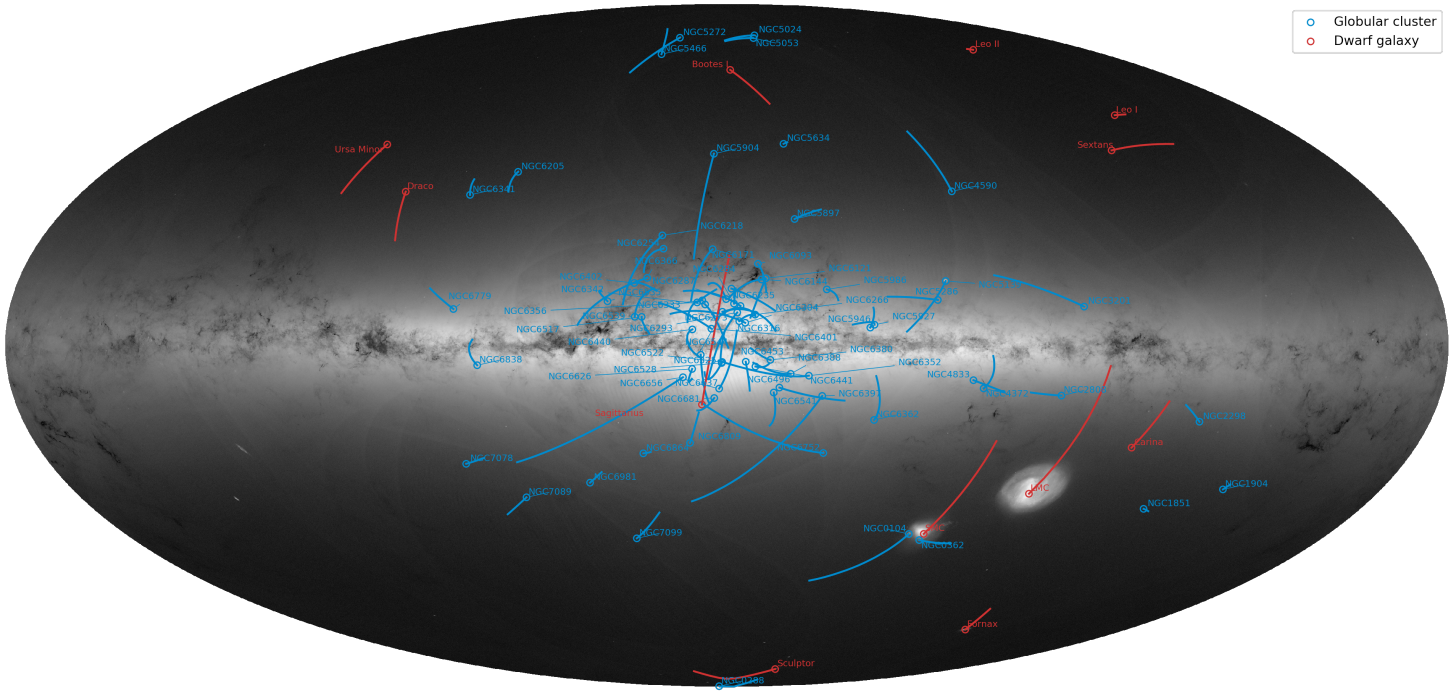
Odenkirchen et al. 2001

Diffuse Stellar Envelopes:



Kuzma et al. 2016

Gaia



Breddels, Helmi, 2018

Membership Probability

After retrieving a radius of 5 deg surrounding ω Centauri (Kuzma et al. 2021), we removed stars that:

- Have colour index G_{BP}-G_{RP}>1.6 mag (removing field dwarfs).
- Stars within 3 kpc with resolved parallaxes.
- Poor or no astrometric solution (re-normalised unit weight error).
- Luminosity fainter than G>19.5 mag.

Devising the Technique

Lastly, we performed isochrone fitting and sigma clipping to select stars that are photometrically consistent with the cluster population.

The likelihood function takes the form of a mixture model, and it contains three components: cluster (cl), extended component (ex) and Milky Way (MW) Foreground.

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

Devising the Technique

Each component has two factors to consider – proper motion and spatial distributions.

Proper motions are modelled as bivariate Gaussian distributions. Cluster + extended components have the same proper motion.

Devising the Technique

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:

$$\Sigma(r,\theta) = r^{-\gamma}(1 + k\ \cos^2(\theta - \theta_{ex}))$$

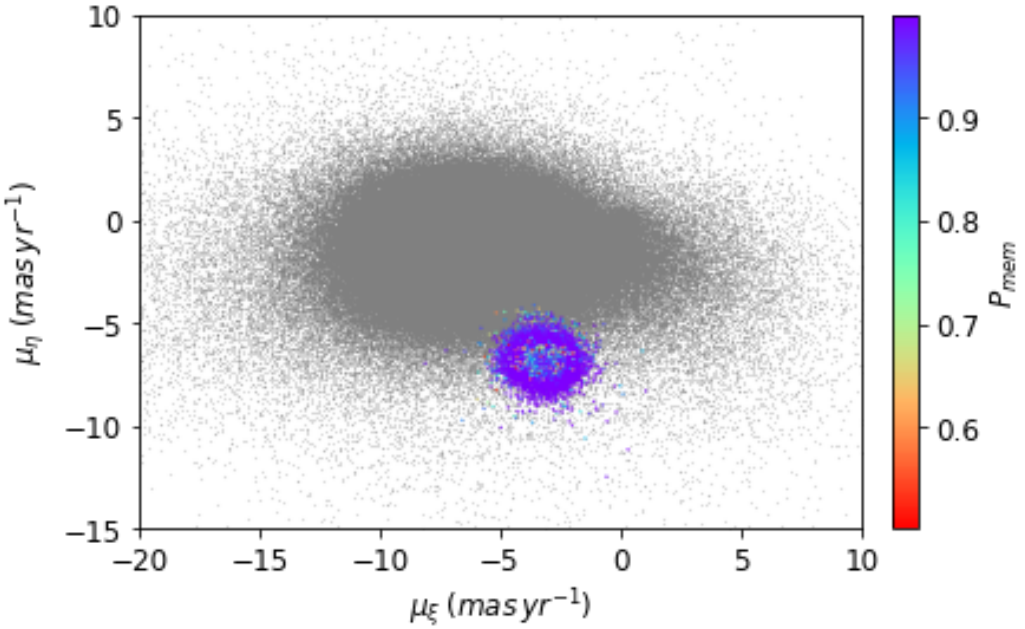
Membership Probability

We use PyMultinest to solve our likelihood function.

We sample the posterior distributions to assign stars a probability that they belong to the cluster + extended component:

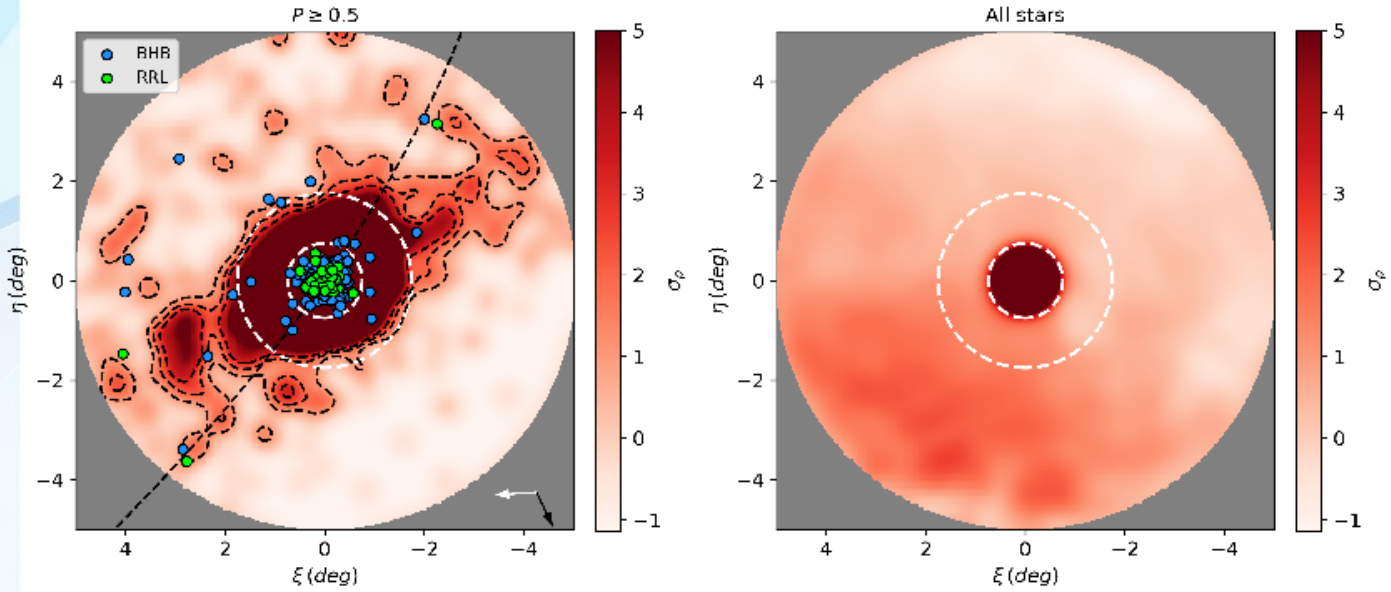
$$P_{mem} = \frac{f_{cl+ex}\left(f_{cl}\mathcal{L}_{cl} + (1 - f_{cl})\mathcal{L}_{ex}\right)}{\mathcal{L}_{tot}}$$

ω Centauri



Proper motion distribution of our highly probable ($P_{mem} \geq 0.5$) (Kuzma et al. 2021)

ω Centauri



2D Surface Density Distribution of ω Cen stars (left). All stars in the sample (right) See also Ibata et al. 2020, Sollima 2020.

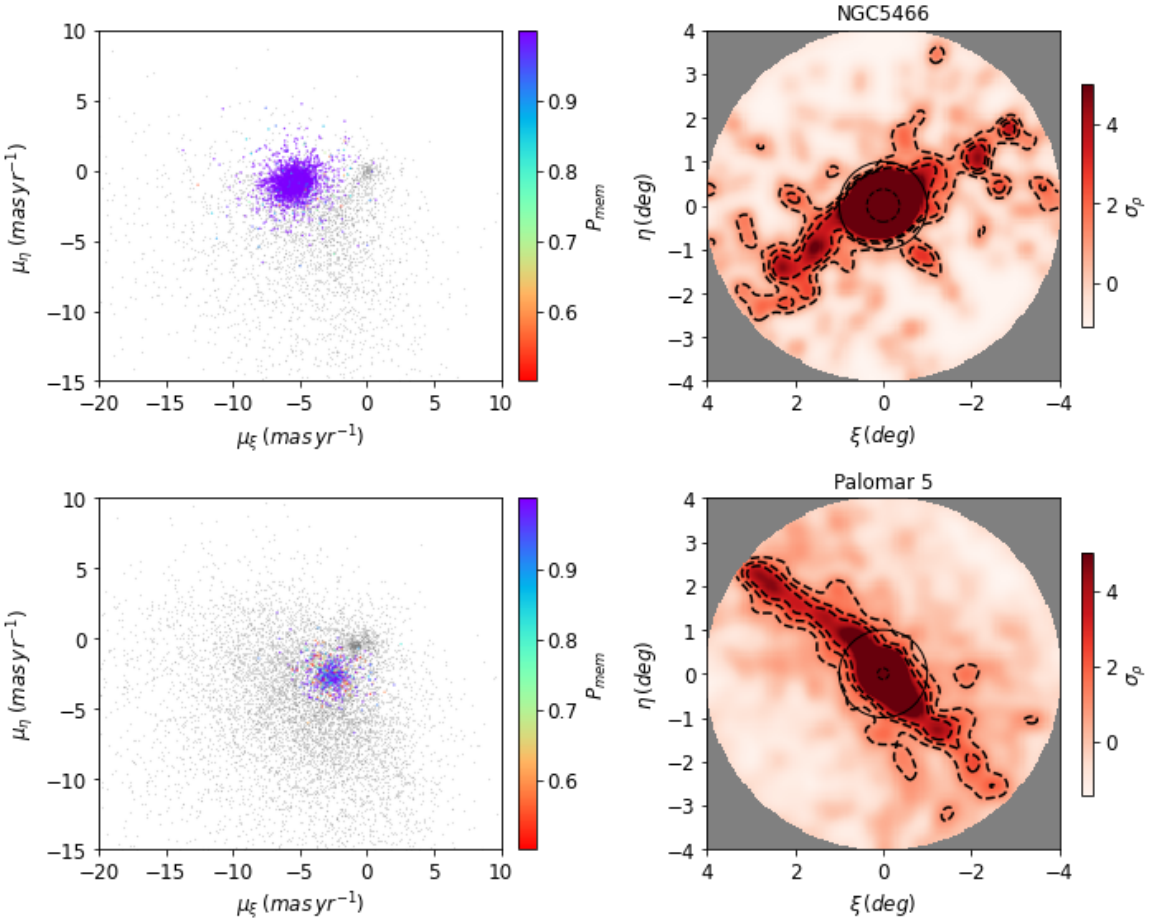
Known Features

We have applied this technique to over 50 GCs (Kuzma et al. 2021b, in prep). In depth exploration currently underway.

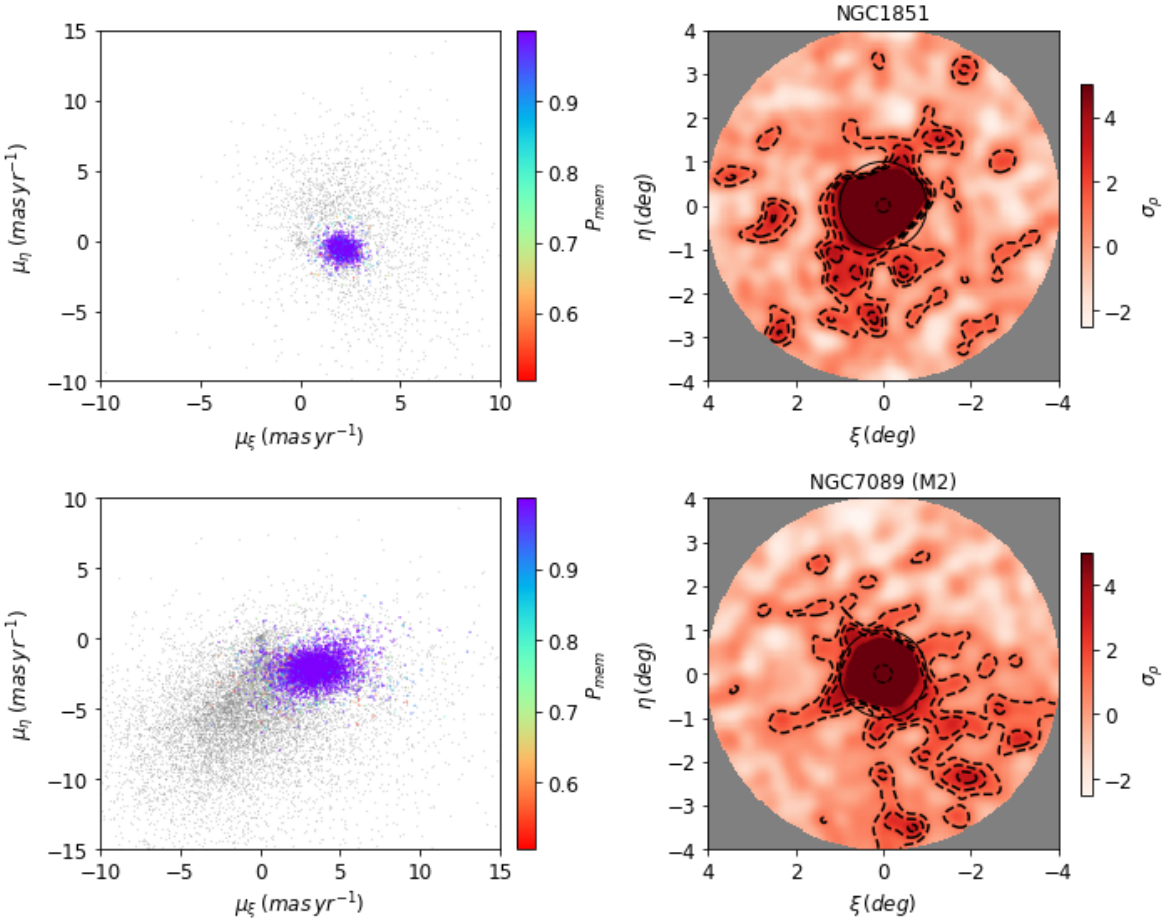
Results for known features:

- Tidal tails (Palomar 5 and NGC 5466)
- Diffuse stellar envelopes (NGC 1851 and M2)

Known Features



Known Features



WEAVE

We have been allocated WEAVE Science Verification (SV) time to conduct a pilot project to study the outskirts of GCs.

We aim to identify stars in the peripheries with radial velocities, perform chemical tagging, and establish 3-D kinematics.

Concluding Comments

- Detection of extended structures amongst 50+ Galactic GCs – detailed exploration in progress.
- Identification of highly probable targets for spectroscopic observations with WEAVE (SV program) and 4MOST.
- First detailed statistical exploration of GC peripheries and their role in the build-up of the Galactic halo.