Stellar Populations in the Milky Way and Beyond
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A Pristine Look at Extended Globular Cluster Structures

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Abstract. Recent developments in Galactic Astronomy reveal that several Milky Way Globular Clusters (GCs) display extended structures, such as tails or diffuse envelopes, sometimes reaching a few hundred parsecs. The number of GCs exhibiting these features has increased since the Gaia Space Mission, which has enhanced our understanding by allowing efficient separation of member stars from foreground and background contaminants. However, Gaia does not provide metallicity data for many stars in and around GCs. The Pristine survey addresses this gap by supplying metallicities for millions of stars, enabling exploration of stellar populations at the tidal radius and beyond. This contribution examines selected GCs with extended structures and presents findings on [Fe/H] distributions beyond tidal radii, with plans for follow-up observations using the Prime Focus Spectrograph on the 8-m Subaru Telescope to advance our understanding of GC peripheral science.

Keywords. stars: abundances – stars: kinematics and dynamics: – globular clusters: general

1. Introduction

The number of Galactic Globular Clusters (GCs) known to possess extended tidal structure has grown since the turn of the century. Ever since the seminal discovery of the tidal tails of Palomar 5 Odenkirchen *et al.* (2003), assessing the fraction of GCs that show signs of disruption or accretion has become highly sought after. Searching for signs of GC disruption or extended GC structures is a difficult task, as you require both deep photometry (e.g., Kuzma *et al.* 2018) to target the stars that are preferentially stripped, and coverage over large patches of sky (e.g., Balbinot *et al.* 2011). Together, this is expensive to achieve and prone to large amounts of Milky Way (MW) field contamination. Extra discrimination can be achieved through the inclusion of new dimensions in the data beyond photometry, such as on-sky proper motions from Gaia (Sollima (2020); Kuzma *et al.* 2021). However, this can still cause some level of contamination and leaves a complete interpretation of the nature of the structure lacking. What is missing is the crucial chemistry of the stars in the extended structure that forms a firm connection between the periphery, the GC, and any stream in the MW halo or the MW itself.

2. The Method

The Pristine survey (Martin *et al.* 2024) provides photometric metallicities and $CaHK$ photometry for millions of stars, and when combined with the Gaia proper motions, can provide the cleanest selection of GCs stars that have been stripped. Here, we utilised the Pristine-Gaia-Synthetic Catalogue to search for extended tidal structure around MW GCs. We adopted a k-nearest neighbour algorithm to identify GC-like stars in a 10-degree field of view centred on 30 GCs across three parameter spaces:

- Gaia Colour-Magnitude space, $(G_{BP,0} - G_{RP,0}, G_0)$

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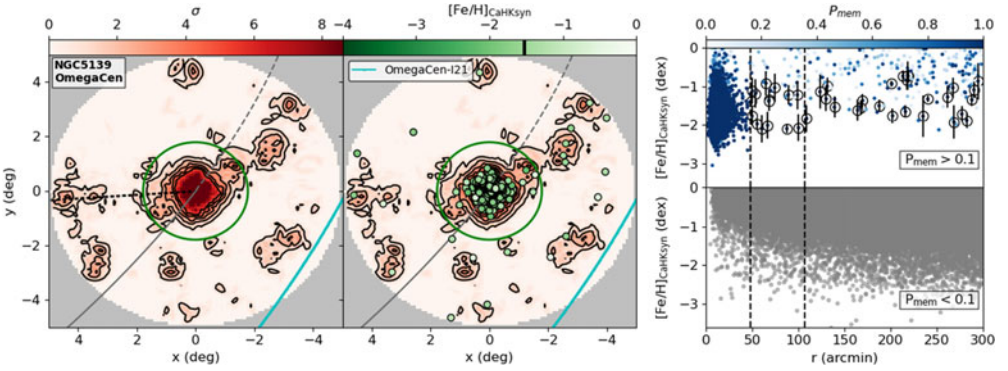


Figure 1. 2D surface density map from the Pristine-Gaia-Synthetic catalogue for NGC 5139 (left and middle) (Kuzma *et al.* 2025). The grey solid (dashed) line demonstrates the forward (backward) integrated orbit, Fimbuthal stream track in cyan (Ibata *et al.* 2019). and the direction to the Galactic Centre is the black dashed line. The Jacobi Radius is shown by the green circle. Right: Metallicity vs clustercentric radius. The top row is the high-probability members, and the bottom is the field contamination in the field of view.

• Pristine-Gaia-Synthetic Colour-Colour Space, $(G_{BP,0} - G_{RP,0}, (CaHK_0 - G_0) - 2.5(G_{BP,0} - G_{RP,0}))$

• Gaia Proper Motions, transformed to a gnomonic-projection coordinate system (μ_x, μ_y)

Each star is assigned a probability of cluster membership through a Gaussian mixture model approach with the above k-nearest neighbour likelihoods. We explored the 2D density maps and the distribution of the highest memberships through an adaptive smoothing kernel, allowing for the high-density regions of cluster members to be smoothed with a smaller kernel, while low-density regions are smoothed with a larger kernel (Fig. 1). We also explore the metallicities of potential members as a function of radius to explore how they are distributed.

3. Towards Subaru and PFS

Due to the faint nature of these structures, the line-of-sight velocities and detailed chemistry needed to fully comprehend the peripheries of GCs are not available. However, new multiplex instruments and telescopes will soon commence science operations. Prime Focus Spectrograph (PFS) is a fibre-fed multiobject spectrograph possessing 2400 fibres on the 8-m Subaru Telescope at Mauna Key. The combination of 2400 fibres on an 8-m class telescope will be extremely effective in covering the GC inner regions, outer periphery and the extended tidal structure to unprecedented photometric depths. GC morphologies, 3D velocity dispersions, and chemistry as a function of radius are all important to understanding how GCs evolve and disrupt, their origins as either in-situ or accreted GCs and how they contribute to the overall assembly of the MW halo.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1743921325001711

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