DISENTANGLING THE COMPONENTS OF THE MILKY WAY

INFERRING THE STRUCTURE OF THE MILKY WAY IN PHASE-SPACE USING GAUSSIAN MIXTURE MODELLING WITH EXTREME DECONVOLUTION

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Motivation and Scientific Justification

Understanding how the Milky Way assembled its structural components is central to the field of Galactic Archaeology. Observational advances, especially through the *Gaia* mission, allow detailed investigation of the chemical and kinematic signatures that trace the Galaxy's formation history. Among these, the existence of a very-metal-poor (VMP) stellar disc presents a key test of disc formation timescales.

Standard models posit that the Galactic disc formed relatively late, from gas that had already been enriched by several generations of star formation. However, if stars with disc-like orbits are observed at metallicities below $[\mathrm{Fe/H}] \lesssim -1.5$, it would suggest that the disc began assembling much earlier—potentially contemporaneous with or even before major accretion events such as Gaia–Sausage/Enceladus. This would challenge prevailing hierarchical-formation narratives and place new constraints on the interplay between in-situ and ex-situ star formation.

The recent study by Zhang et al. [1] introduced a compelling statistical framework for testing this idea using Extreme-Deconvolution Gaussian Mixture Modelling (XD-GMM). Their findings argue against a cold, rotationally supported VMP disc. However, the method's sensitivity to substructure, selection effects, and chemical splits (such as alpha abundance) invites closer scrutiny.

This project builds on their approach in two ways. First, we reproduce their metallicity-binned XD-GMM decomposition using the same Gaia DR3-based red giant catalogue. Second, we extend their analysis by splitting the sample into high- and low-alpha sequences using methodology proposed by Viswanathan et al. [2], testing whether disc-like kinematics emerge at different metallicities within each branch. In doing so, we aim to clarify whether previous disc-like signals at low metallicity reflect genuine early disc formation or instead arise from noise, misclassification, or accreted debris.

The scientific justification rests on the idea that even a small population of metal-poor stars with coherent, disc-like kinematics could alter our understanding of the Galaxy's early history. By carefully quantifying kinematic structure across chemical space—and explicitly accounting for measurement uncertainties—we contribute to a clearer, more robust reconstruction of the Milky Way's formation pathway.

References

[1] Hanyuan Zhang, Anke Ardern-Arentsen, and Vasily Belokurov. On the existence of a very metal-poor disc in the milky way, 2024.

[2] Akshara Viswanathan, Danny Horta, Adrian M. Price-Whelan, and Else Starkenburg. A slow spin to win – the gradual evolution of the proto-galaxy to the old disc, 2024.