Finding stellar streams and tidal tails using Bayesian mixture models

Andrew Li | Supervised by Ting Li and Gustavo Medina

University of Toronto, Dunlap Institute for Astronomy and Astrophysics

UNIVERSITY OF TORONTO

DUNLAP INSTITUTE for ASTRONOMY & ASTROPHYSICS

Introduction

In the outer halo of our Milky Way resides many old globular clusters and dwarf galaxies. These ancient structures contain an abundance of information about the early universe, including the nature of our Milky Way's formation and its dark matter structure. **Stellar streams** appear as a long line of stars in the sky and occur when one of these structures undergoes immense tidal stripping from the host galaxy. **Tidal tails** are similar structures, only the extent of the tidal stripping is comparatively minimal, resulting in what appears to be a protruding 'tail'.

Streams and tails have proved difficult to detect due to their great distance. This research addresses these issues by modelling a population using **Bayesian mixture models** based on their properties and Markov chain Monte Carlo is used to find optimal parameters, and subsequently the likely stream members.

Data

The data used in this research is the latest Southern Stellar Stream Spectroscopic Survey[1] (S5) data, which has surveyed 20 stellar streams and many more GCs and DGs in the southern sky. Stream coordinates (ϕ_1, ϕ_2) are used in place of **(RA,Dec)** to center and rotate the streams for easier analysis. Radial velocity is also converted from heliocentric to the Galactic Standard of Rest (v_{GSR}) to remove solar motion.

Currently, Twelve stellar streams, six globular clusters, and seven dwarf galaxies have been successfully modelled, with more planned.

Models

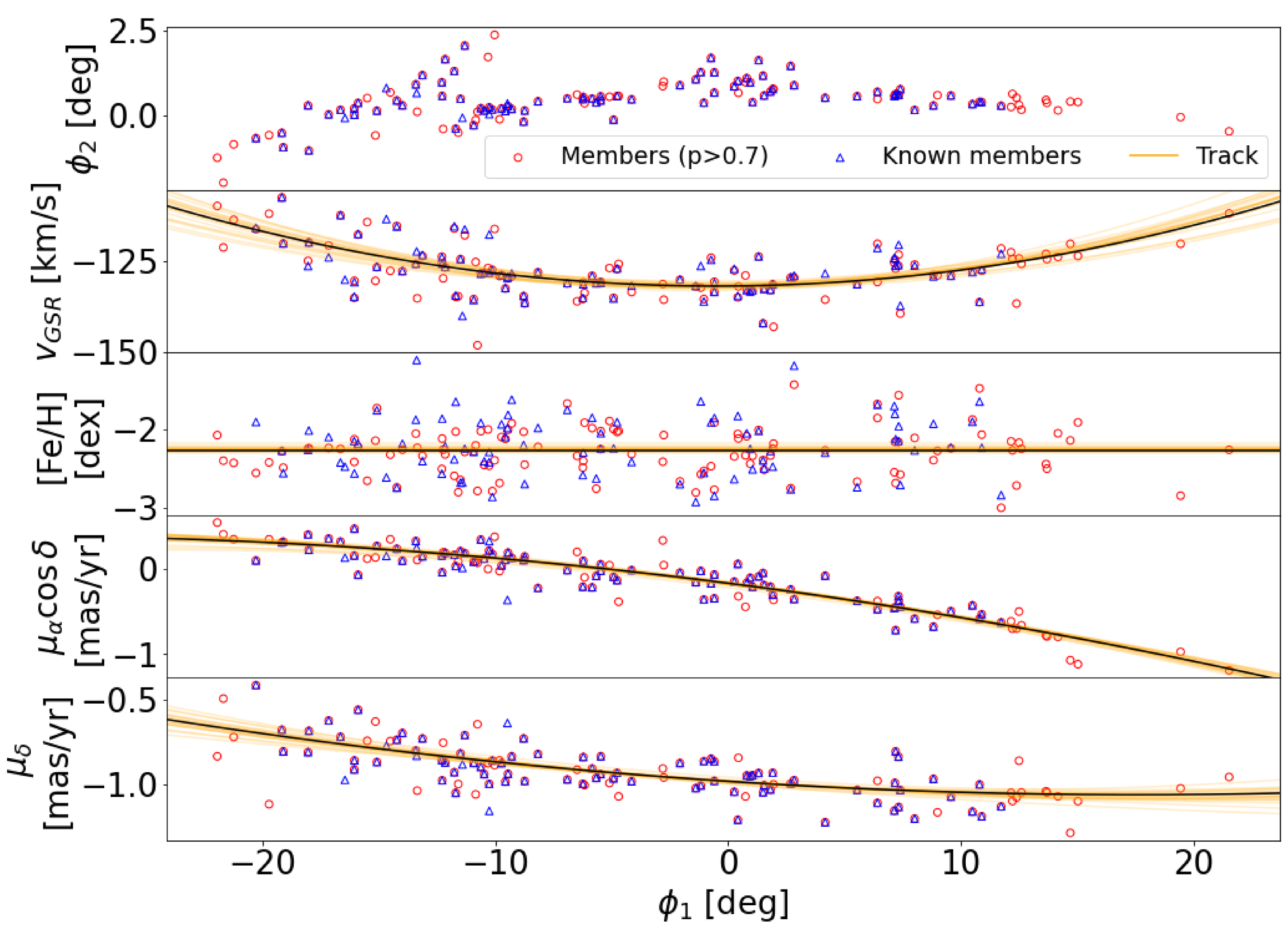
Models may vary depending on the target, but follow the same structure. There is a stream component and a background component, each a summation of the pdfs of

1. **Radial velocity** as a 1-d Gaussian,
2. **Metallicity** as a 1-d Gaussian,
3. **Proper motion** in right ascension and declination as a 2-d Gaussian with covariance.

The stream component means of radial velocity and proper motion are also taken as a quadratic function of $x = \phi_1/10°$.

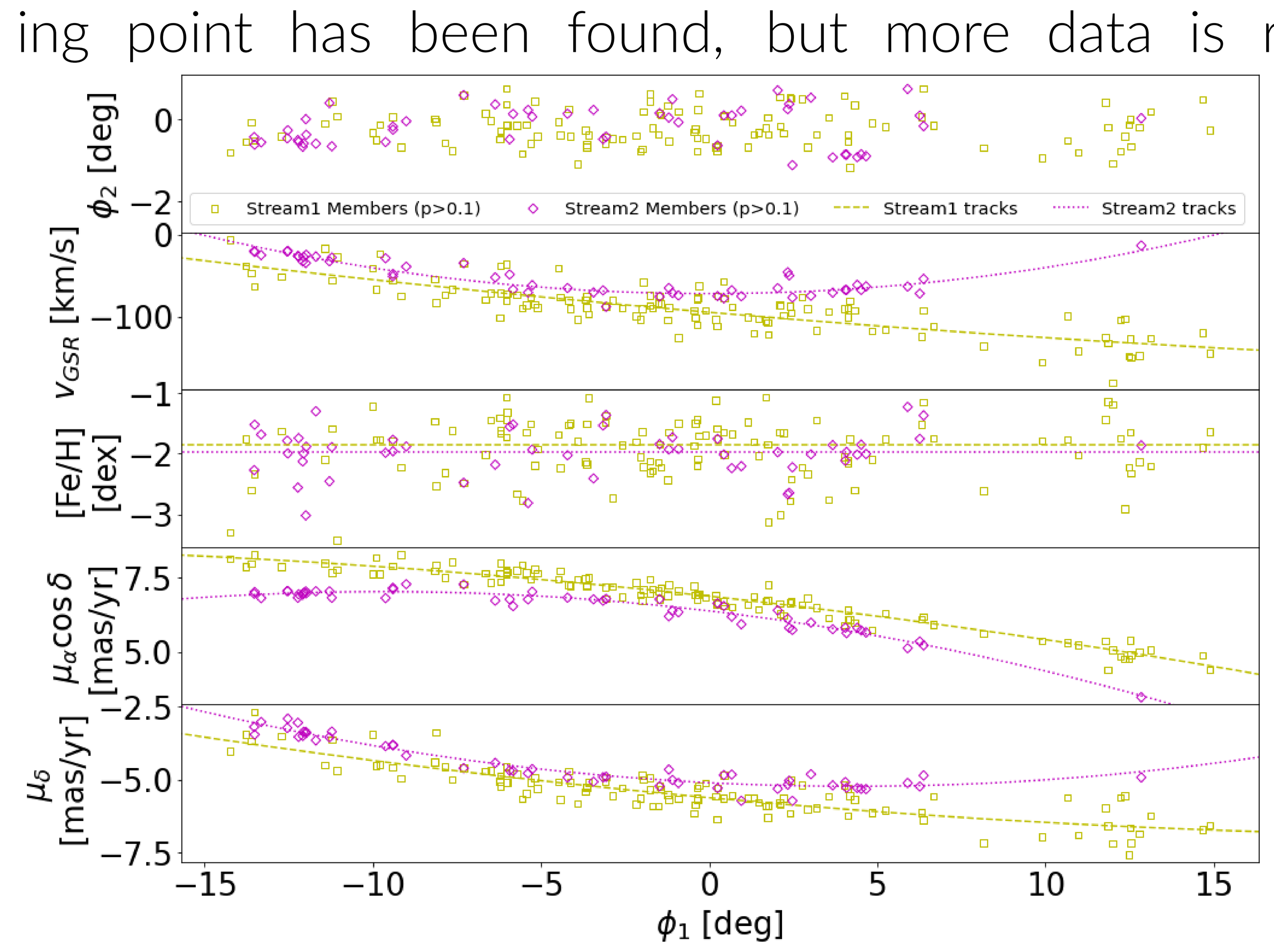
ATLAS Aliqa-Uma (AAU), stellar stream

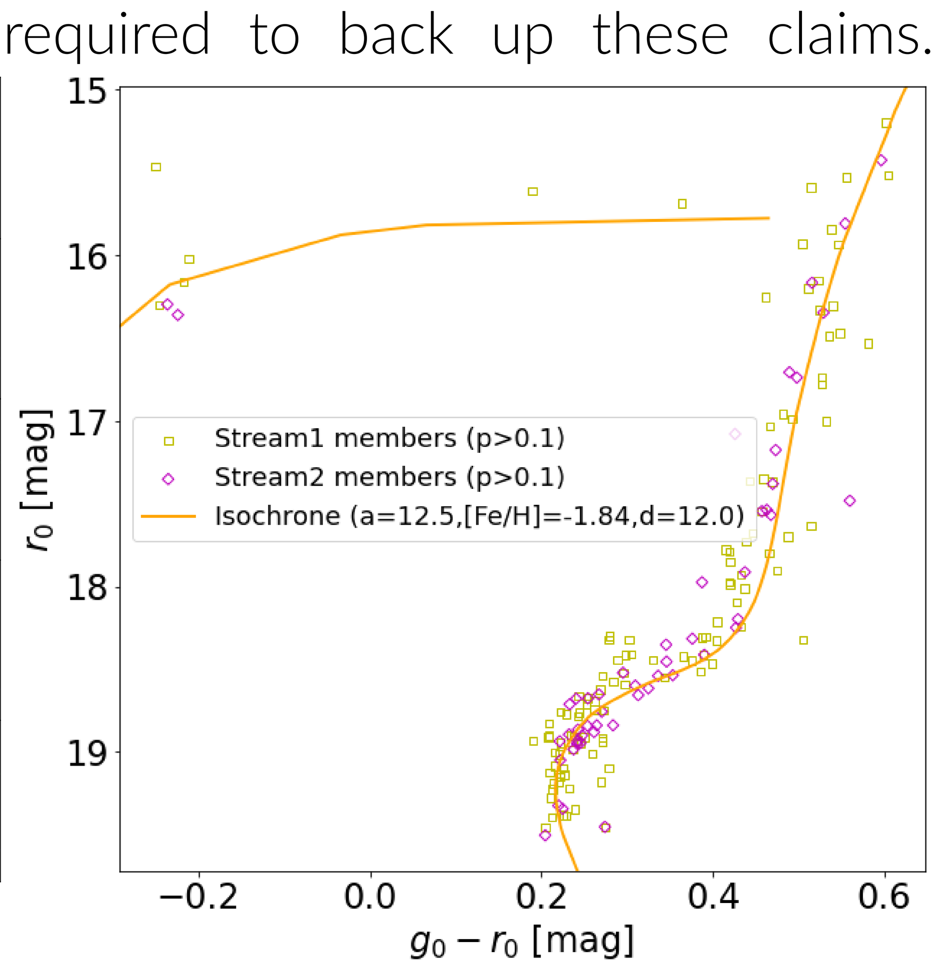
Originally discovered as **two separate** streams, ATLAS Aliqa-Uma was theorized in 2021[2] to be **one big stream** with the misalignment caused by a run-in with the LMC. The modelling found all members of both streams detailed in the paper using just one stream component, supporting the claim that AAU is in fact one large stream. In the figure on the right, the tracks are shown by the orange lines, which are drawn from the posterior.



Jhelum, stellar stream

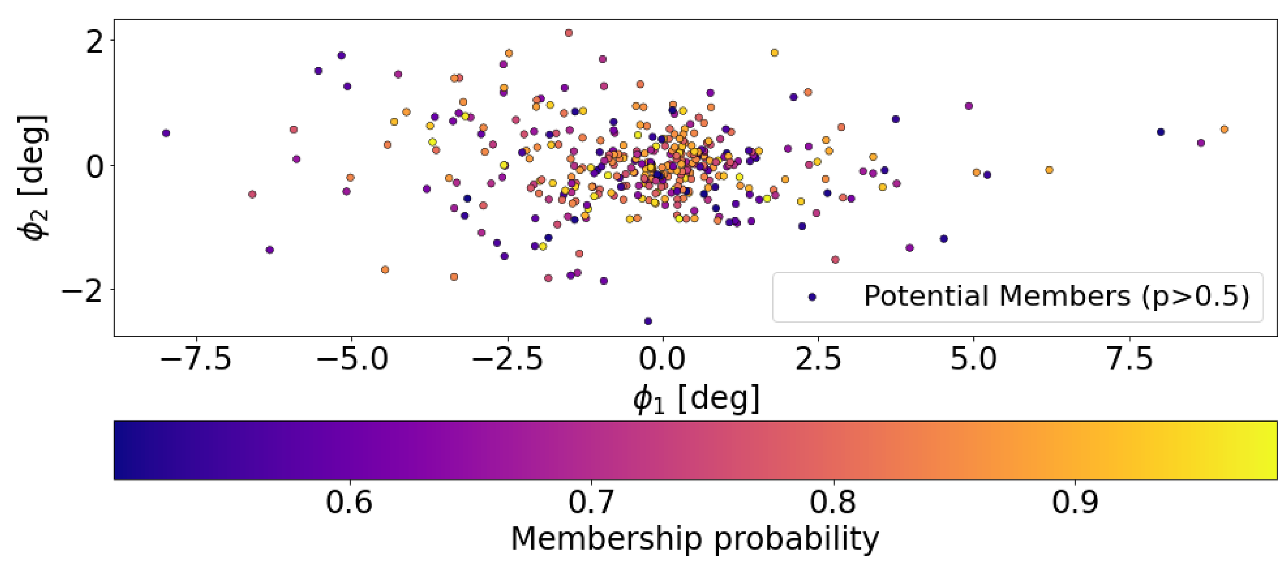
New findings suggest Jhelum is comprised of **two populations**. The figures below show these two populations in yellow (stream1) and magenta (stream2). The differences in proper motion are most notable, and the CMD might suggest a slight difference in distance. The velocity and metallicity dispersions are also roughly **three times larger** in stream1 than stream2, which suggests stream1's progenitor was a dwarf galaxy and stream2's progenitor was a globular cluster. A good starting point has been found, but more data is required to back up these claims.





Antlia II, Dwarf Galaxy

Potential **tidal tail** features of Antlia II can be seen in the spatial plot on the right. Probable members extend outwards roughly between roughly $\phi_1 = -8°$ and $\phi_1 = 10°$, but extend only around $4°$ along ϕ_2.



Conclusion and Outlook

Although successful for most targets, the model does not always accurately represent the data, which can diminish success in this method. Further refinements will be made to the model to address issue, which should allow for more results in the future.

References

[1] Li, T. S., Koposov, S. E., Zucker, D. B., et al. 2019, Monthly Notices of the Royal Astronomical Society, 490, 3508, doi: `10.1093/mnras/stz2731`

[2] Li, T. S., Koposov, S. E., Erkal, D., et al. 2021, , 911, 149, doi: `10.3847/1538-4357/abeb18`