Sifting for a Stream: An Analysis of the Morphology of the 300S Stellar Stream

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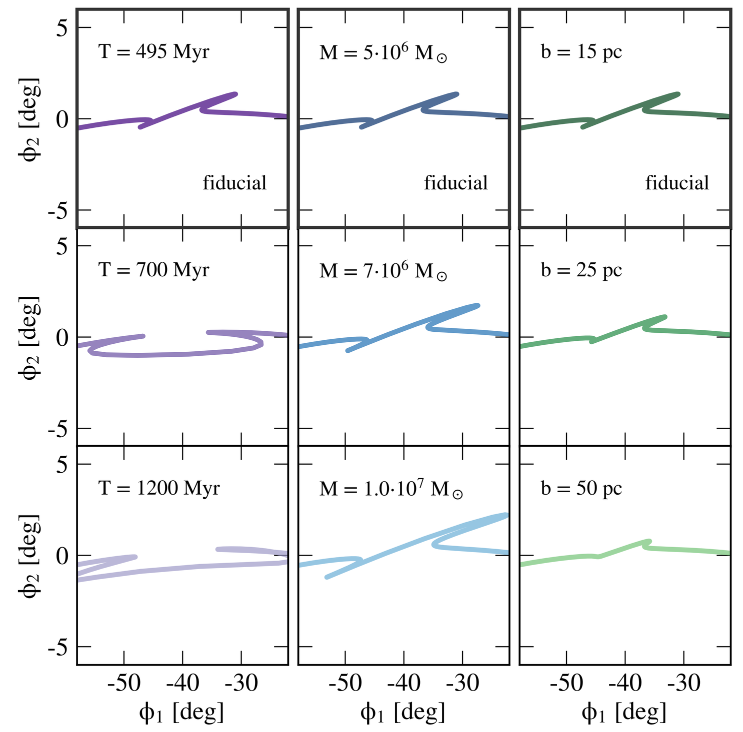
Introduction and Background

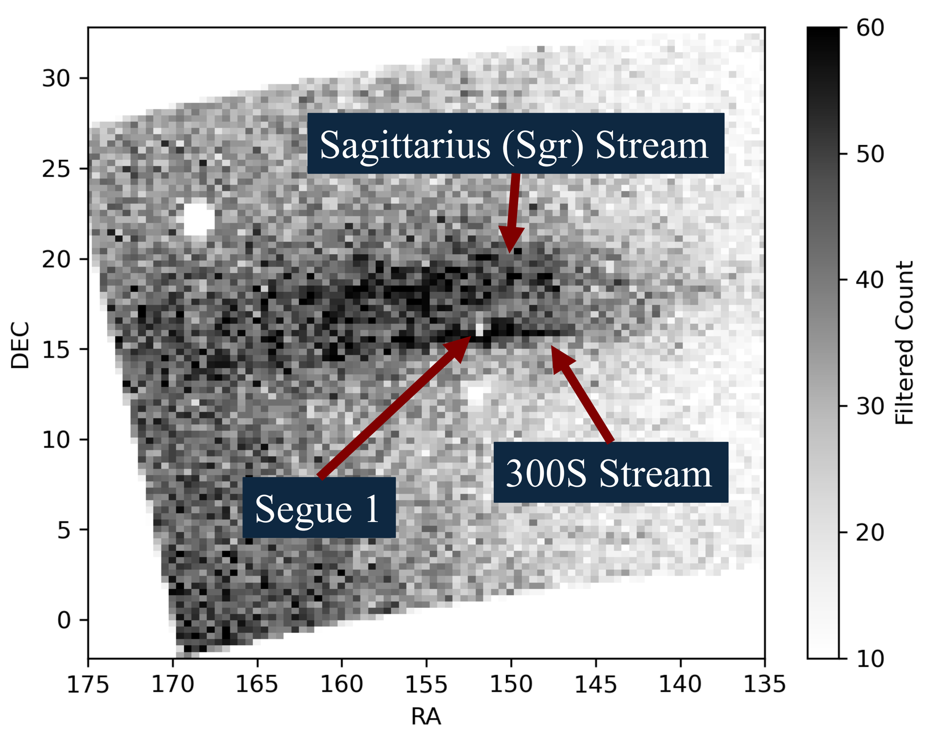
Stellar Streams as Laboratories for Small Scale Milky Way Structure

- Dark matter models predict different small-scale structures.
- Stellar stream perturbations indicate potential interactions with dark matter halos, including star-free halos.
- Measuring stream morphology can probe this small-scale structure.



Modeled stream perturbations in GD-1 under different encounter parameters *[1]*.

The 300S Stellar Stream



Matched filter map of 300S with visible objects labelled.

- Retrograde orbit with high eccentricity *[2]*
  - Galactic pericenter: ~4.1kpc
  - Galactic apocenter: ~60kpc
- Extends from RA ~144° to ~168°
- [FeH] = −1.35, Age = 12.5 Gyr *[3]*
- Likely was a globular cluster progenitor *[3]*

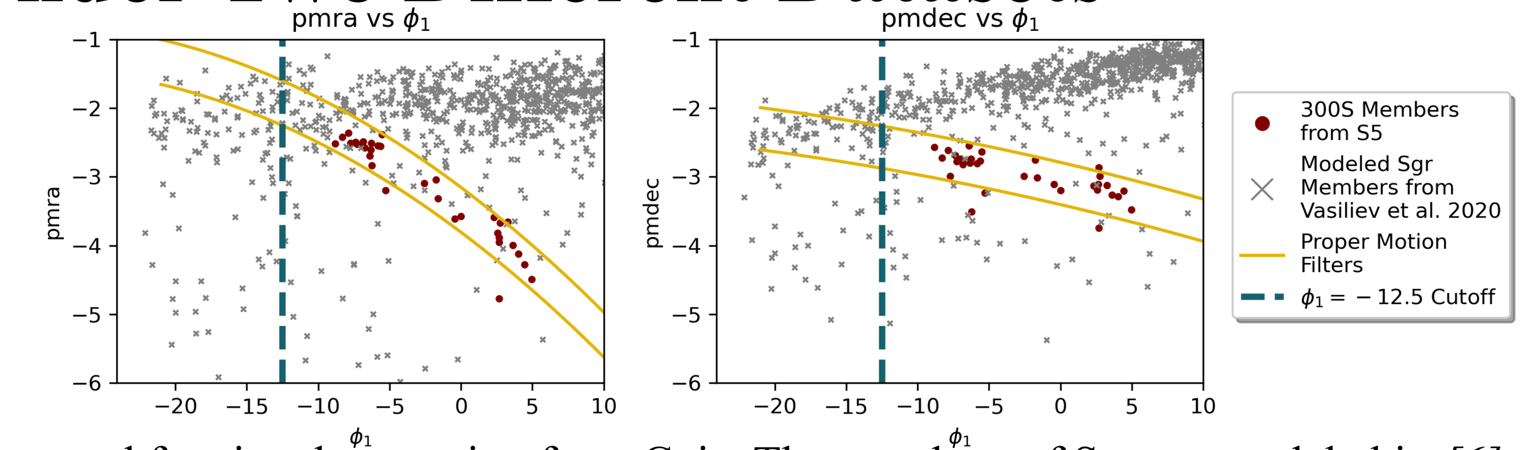
Objective

Improve models of stream morphology in a manner robust to background contamination.

Extracting Stream Morphology Under Two Different Datasets

Filtering Out Sgr Using Proper Motions from Gaia DR3

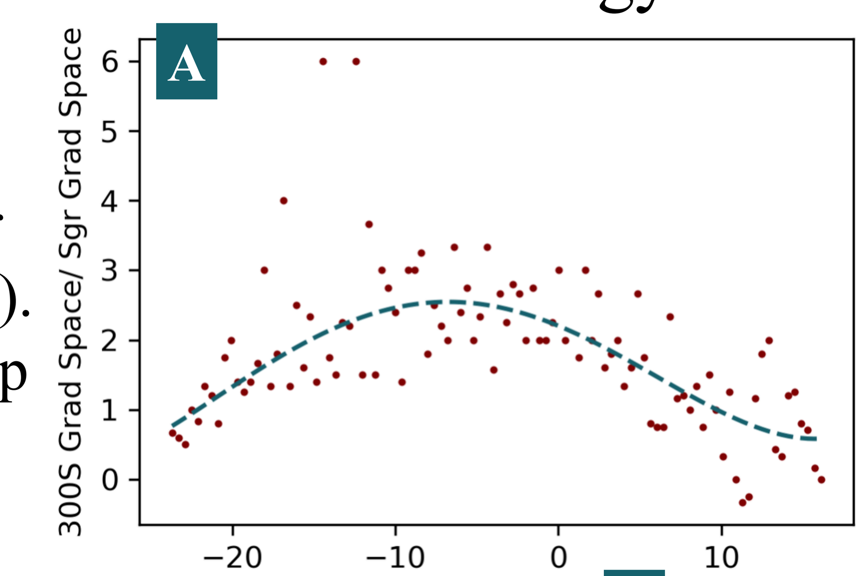
- Quadratic fit to S5 member *[4]* PMs with 1.5σ cut filters.
- Stars further selected with filter on turnoff, sub-giant, and red-giant regions.
- $\phi_1 < -12.5$ cut due to Sgr contamination.
- Signal vanishes at $\phi_1 > 5$.



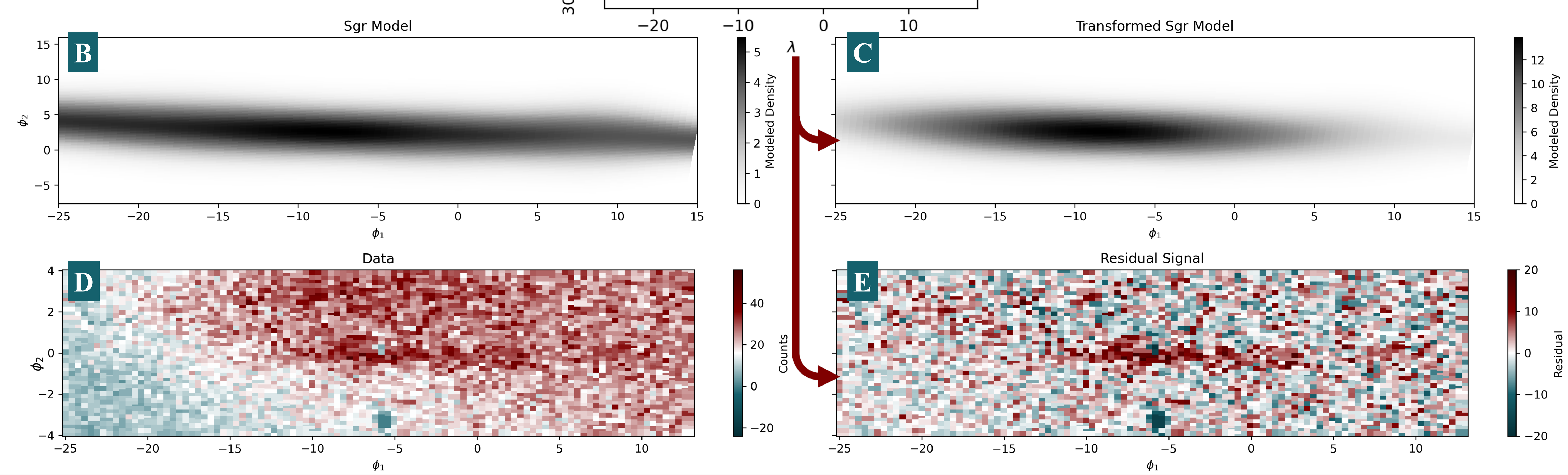
Proper motion filters used for signal extraction from Gaia. The members of Sgr are modeled in *[6]*.

Subtracting Out Sgr Using Photometry from the Dark Energy Camera Legacy Survey (DECaLS) DR9

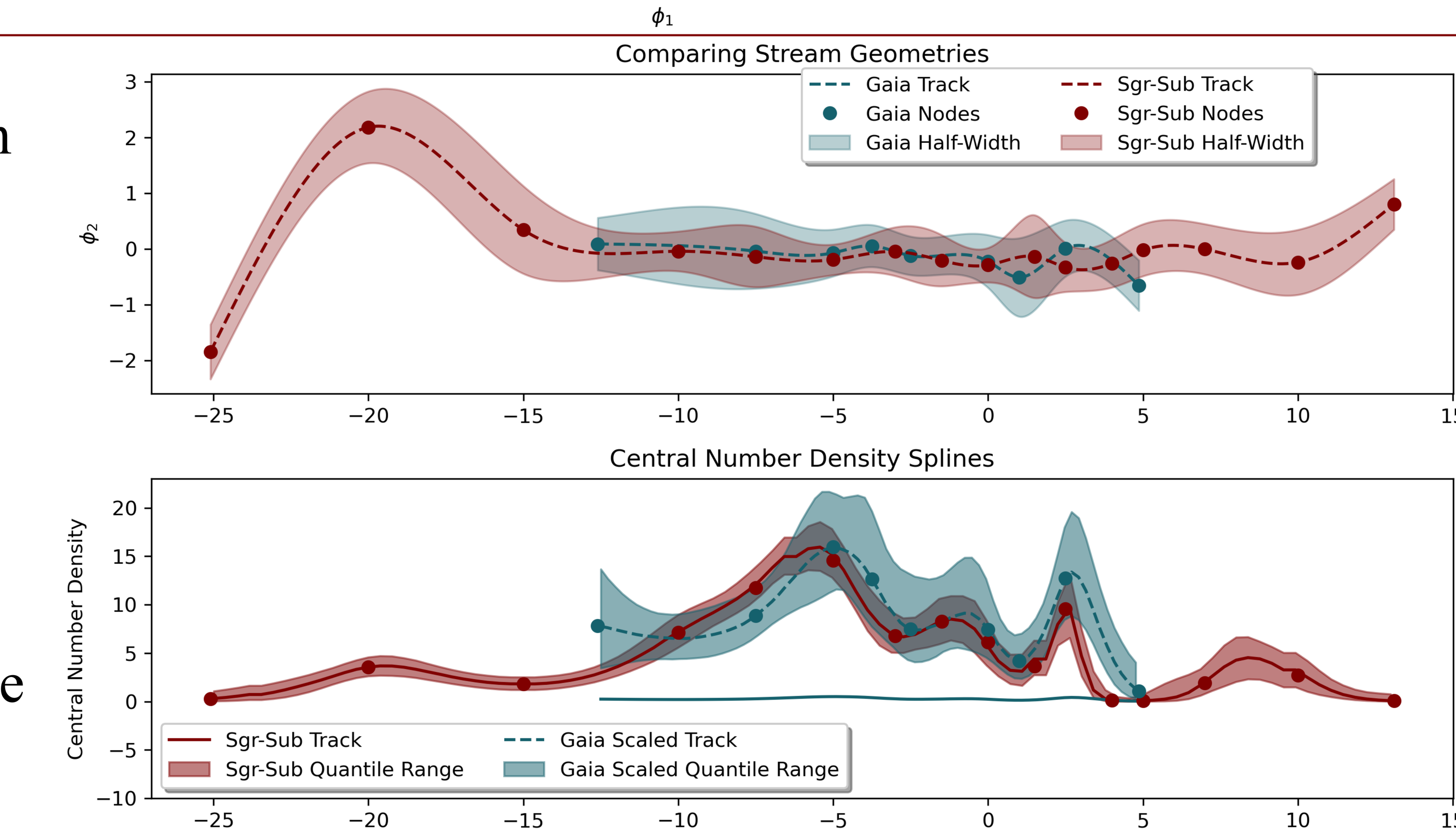
- New distance gradient empirically fit on Sgr's response to the 300S matched filter.
- Polynomial fit on ratio of Sgr signals under 300S and Sgr gradients along Sgr's axis (A).
- Model of Sgr fit onto the stellar density map filtered using the Sgr distance gradient (B).



- Sgr model transformed into the map filtered with 300S's gradient using transformation polynomial (from B to C).
- This transformed Sgr model allows us to subtract out the influence of Sgr and extract the 300S signal (from D to E).



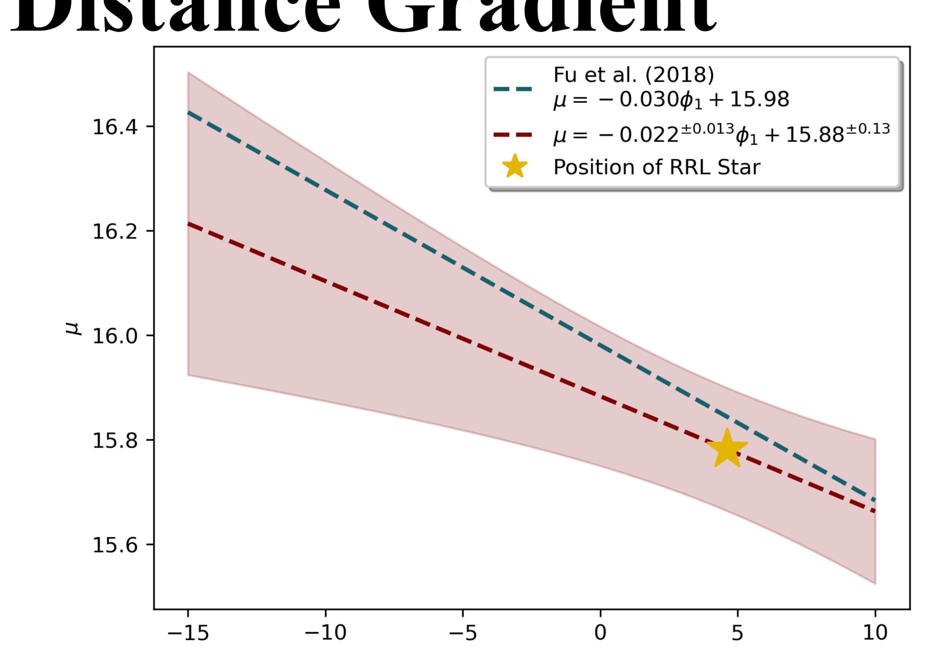
- Stream model: cubic splines for central number density, gaussian width, and ϕ_2 as functions of ϕ_1. Background and Sgr also modeled with splines.
- Assume the data are Poisson distributed in each spatial bin. The models then represent the spatial distribution of the Poisson's mean.
- Models fit to number density maps with MCMC as in *[5]*.
- For better comparison, Gaia model's central number density scaled so its maximum value is equivalent to the maximum of the Sgr-Sub model's central number density.



Final stream models. (Top) Stream tracks and half-widths overplotted. (Bottom) Stream central number density splines with 16% − 84% quantiles overplotted.

Reobtaining a Distance Gradient

- We identify one RR Lyrae (RRL) and no Blue Horizontal Branch stars consistent with our proper motion filters and the approximate distance.
- 0-point determined by RRL star.
- Slope determined by high purity RGB catalog from S5 *[4]*. Slope fit to their deviations from an isochrone as a function of ϕ_1.
- Result in agreement with distance gradient from *[2]* once that gradient is transformed into our ϕ_1 and ϕ_2 space.



Resulting distance gradient with uncertainties. Our fit is slightly closer and more gradual than the *Fu et al. 2018 [2]* gradient, though they agree.

Conclusions

- Both methods of signal extraction yield agreeing stream parameters across 300S's footprint.
- The stream parameters vary relatively smoothly with no visible kinks.
- Intensity drops off between the peaks, indicating a slight gap in the stream.
- Further work necessary to verify behavior at $\phi_1 < -12.5$ where Gaia model is contaminated.

References

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[3] Usman, S. A. et al. (2024). *Multiple Populations and a CH Star Found in the 300S Globular Cluster Stellar Stream*. https://arxiv.org/abs/2401.02476

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[6] Vasiliev, E., Belokurov, V., & Erkal, D. (2020). Tango for three: Sagittarius, LMC, and the Milky Way. *Monthly Notices of the Royal Astronomical Society*, *501*(2), 2279–2304. https://doi.org/10.1093/mnras/staa3673