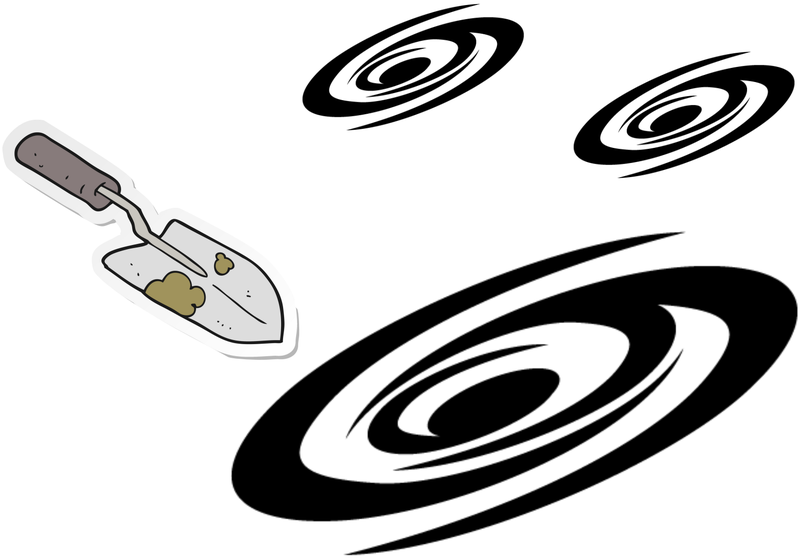
Searching for a disrupted dwarf binary in Sagittarius

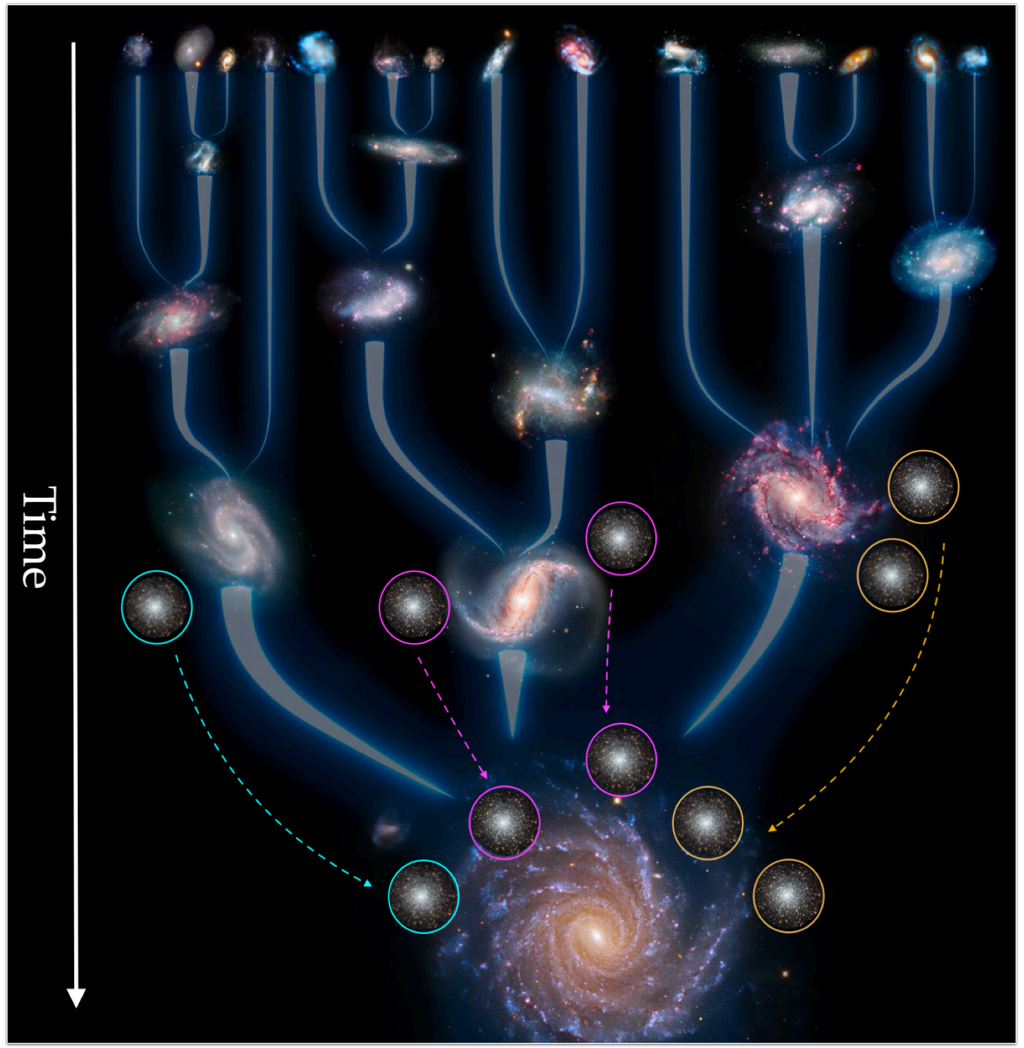
Uncovering the accretion history of the Milky Way with Galactic Archaeology



Elliot Y. Davies (Institute of Astronomy, Cambridge)

Collaborators: **Vasily Belokurov,** N. Wyn Evans, **Stephanie Monty, Adam M. Dillamore**

How do galaxies form?



Credit: ESO/L. Calçada

Evidence for hierarchical formation

The Sagittarius dwarf galaxy

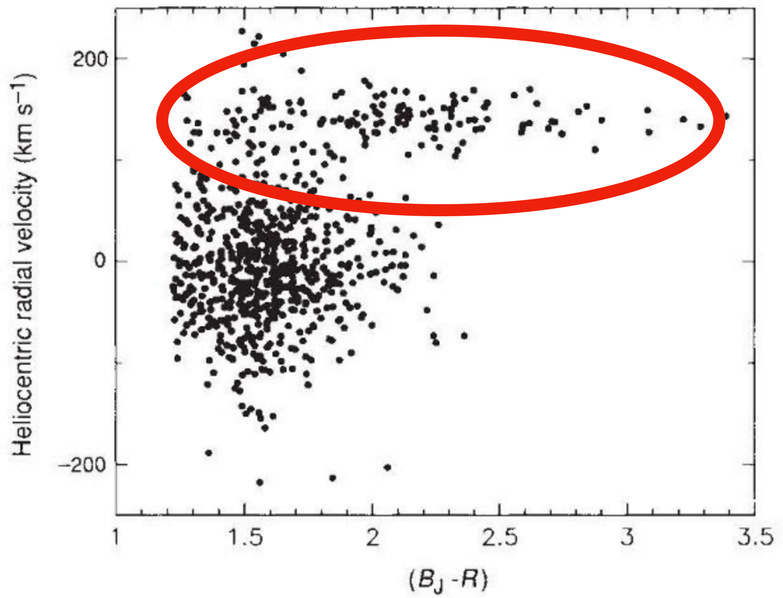
LETTERS TO NATURE

A dwarf satellite galaxy in Sagittarius

R. A. Ibata*, G. Gilmore* & M. J. Irwin†

* Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK
† Royal Greenwich Observatory, Madingley Road, Cambridge CB3 0EZ, UK

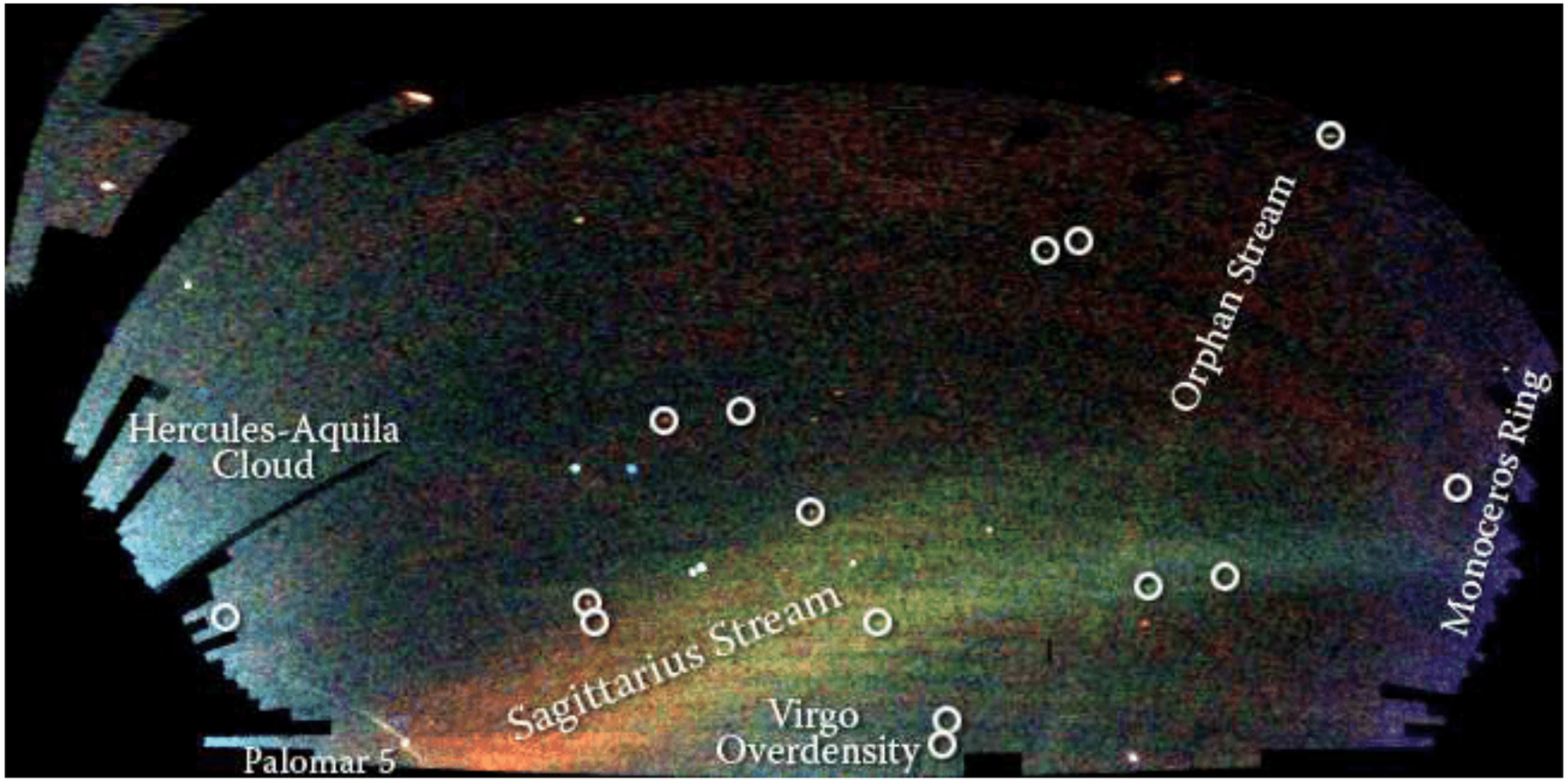
NATURE · VOL 370 · 21 JULY 1994



Unexplained features of Sagittarius

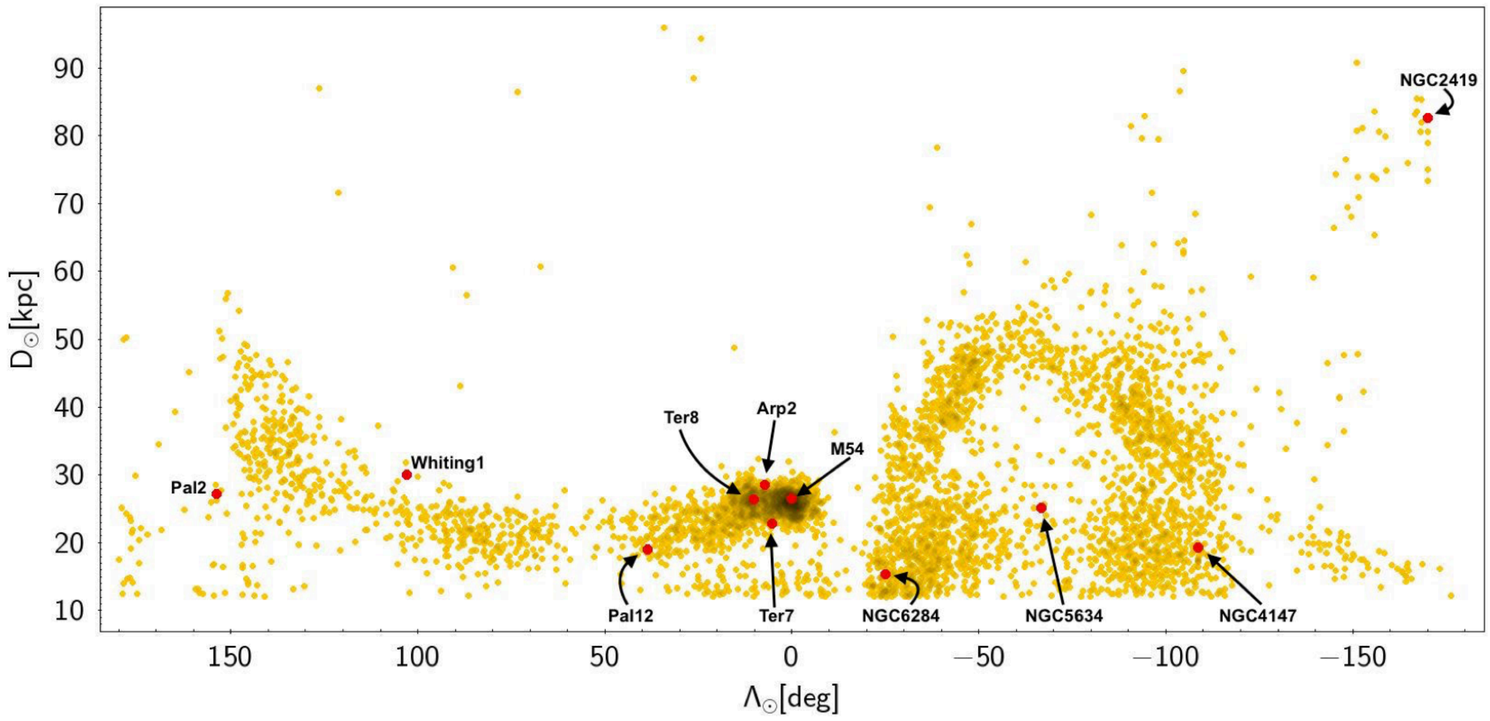
The stream of Sagittarius forks into two branches

Credit: V. Belokurov et al. (2006)

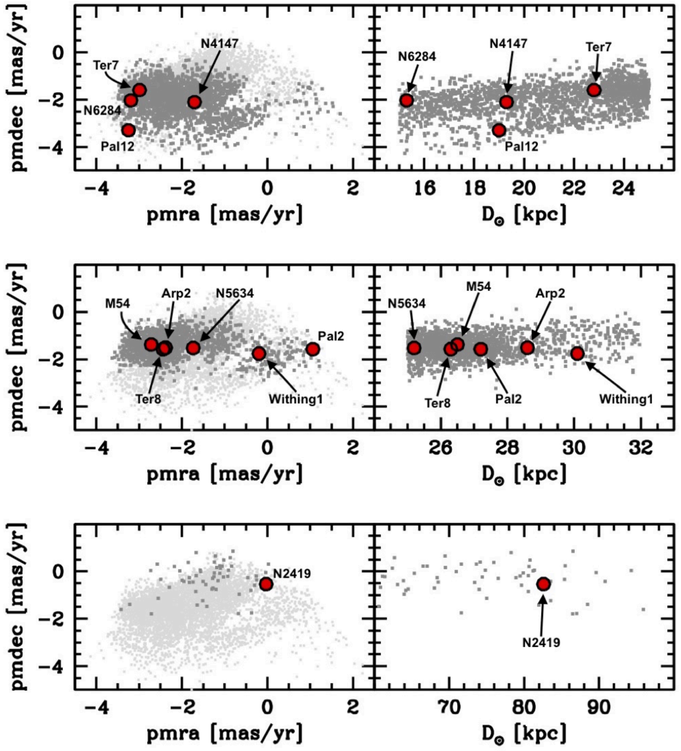


The globular clusters of Sagittarius

Globular clusters whose properties overlap with Sagittarius.



Credit: M. Bellazzini (2020)



The globular clusters of Sagittarius

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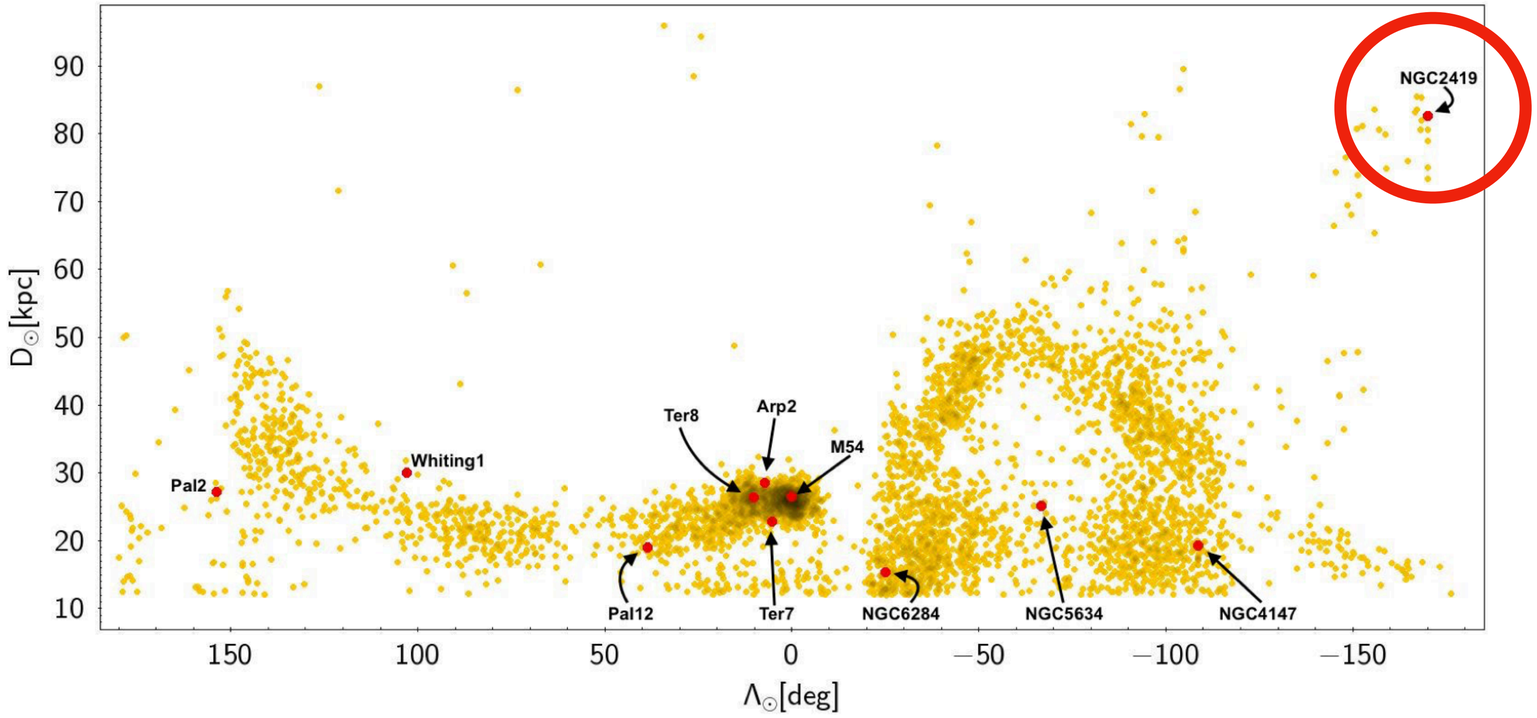
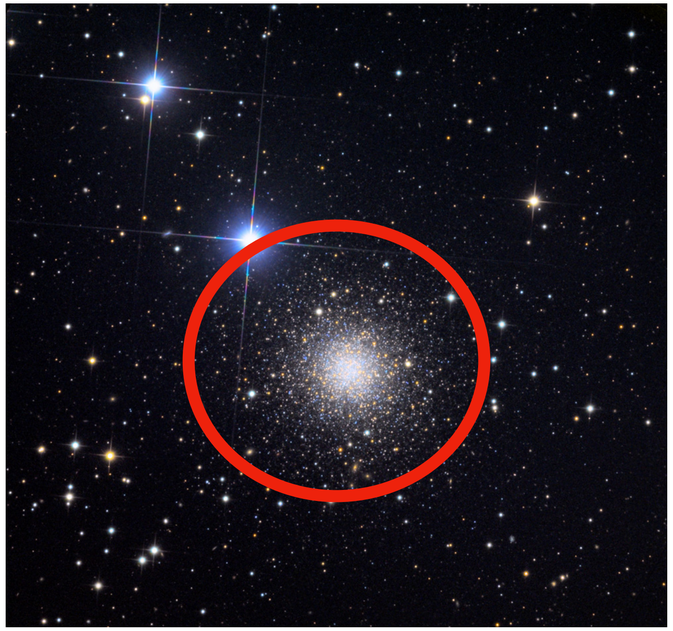




NGC 2419 (the ~~intergalactic~~ wanderer)

An atypically large half light radius

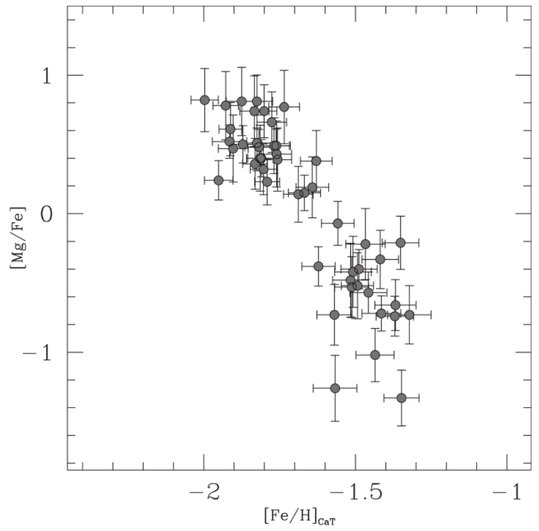
Around 90 kpc from the Galactic centre

Found within the tail of Sagittarius

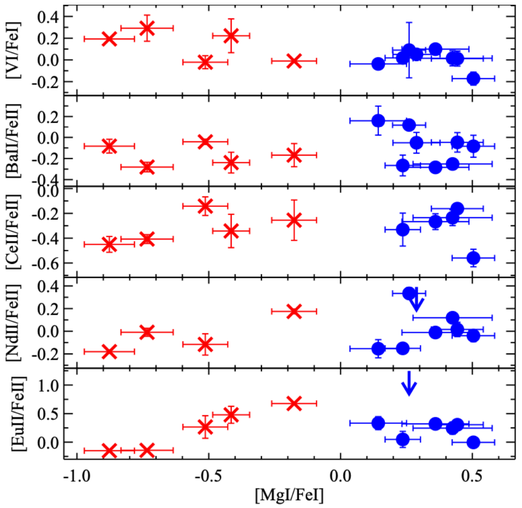
Two chemical populations

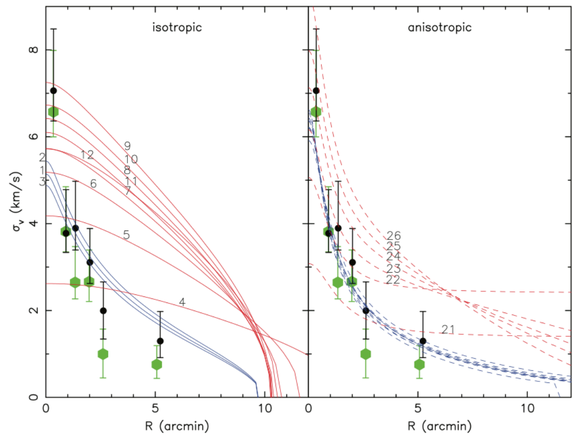
Deficient in dark matter

Credit: A. Mucciarelli et al. (2012)

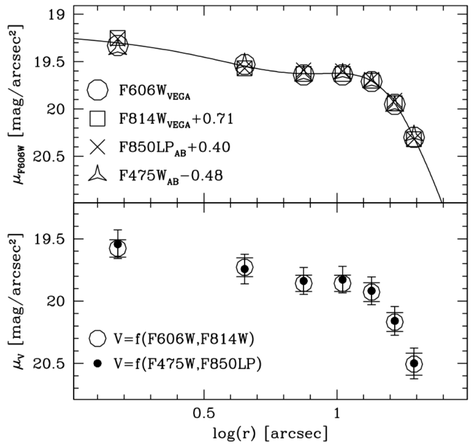


Credit: J. Cohen et al. (2012)





Credit: R. Ibata et al. (2011)

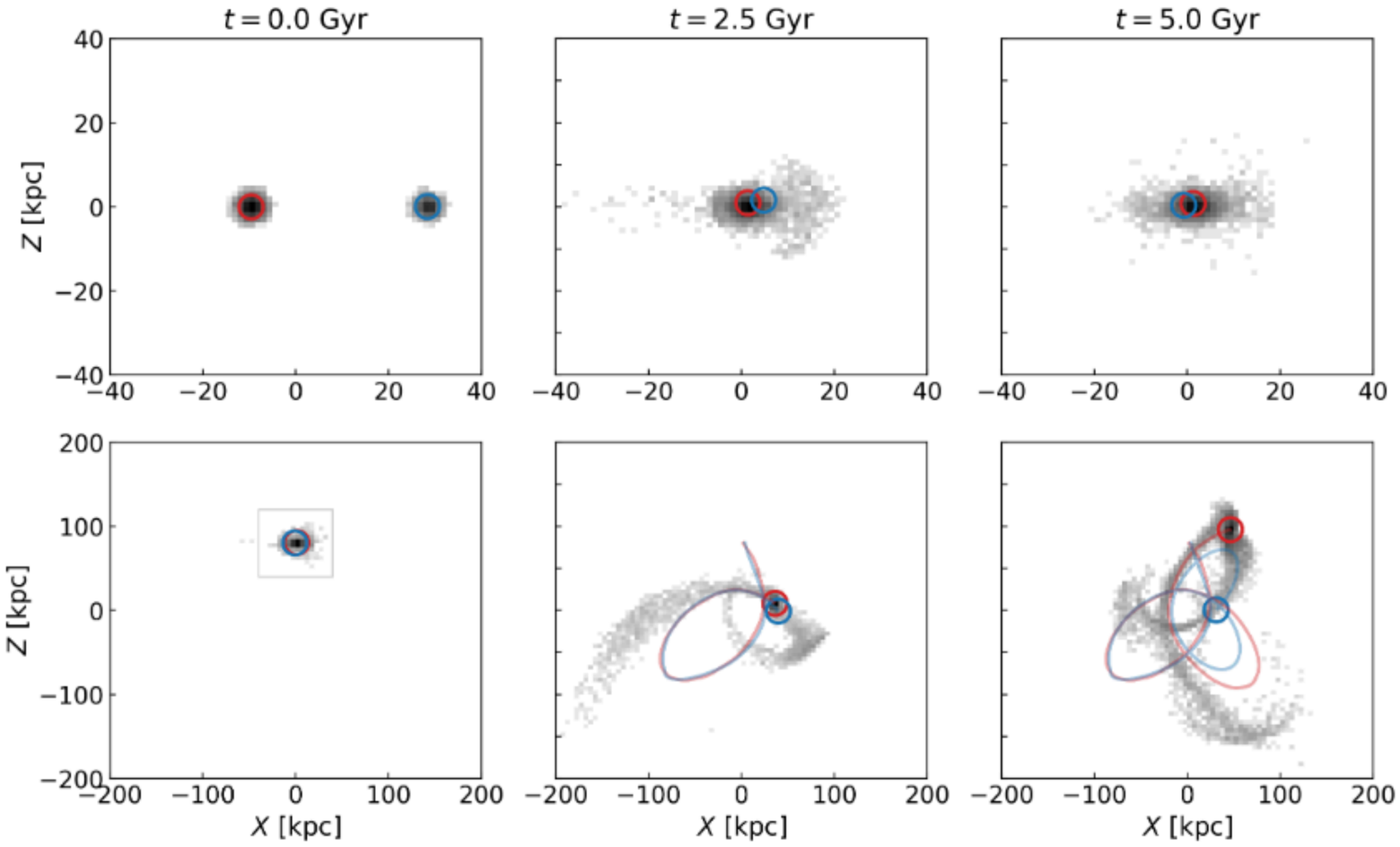


Credit: M. Bellazzini (2011)

A new explanation?

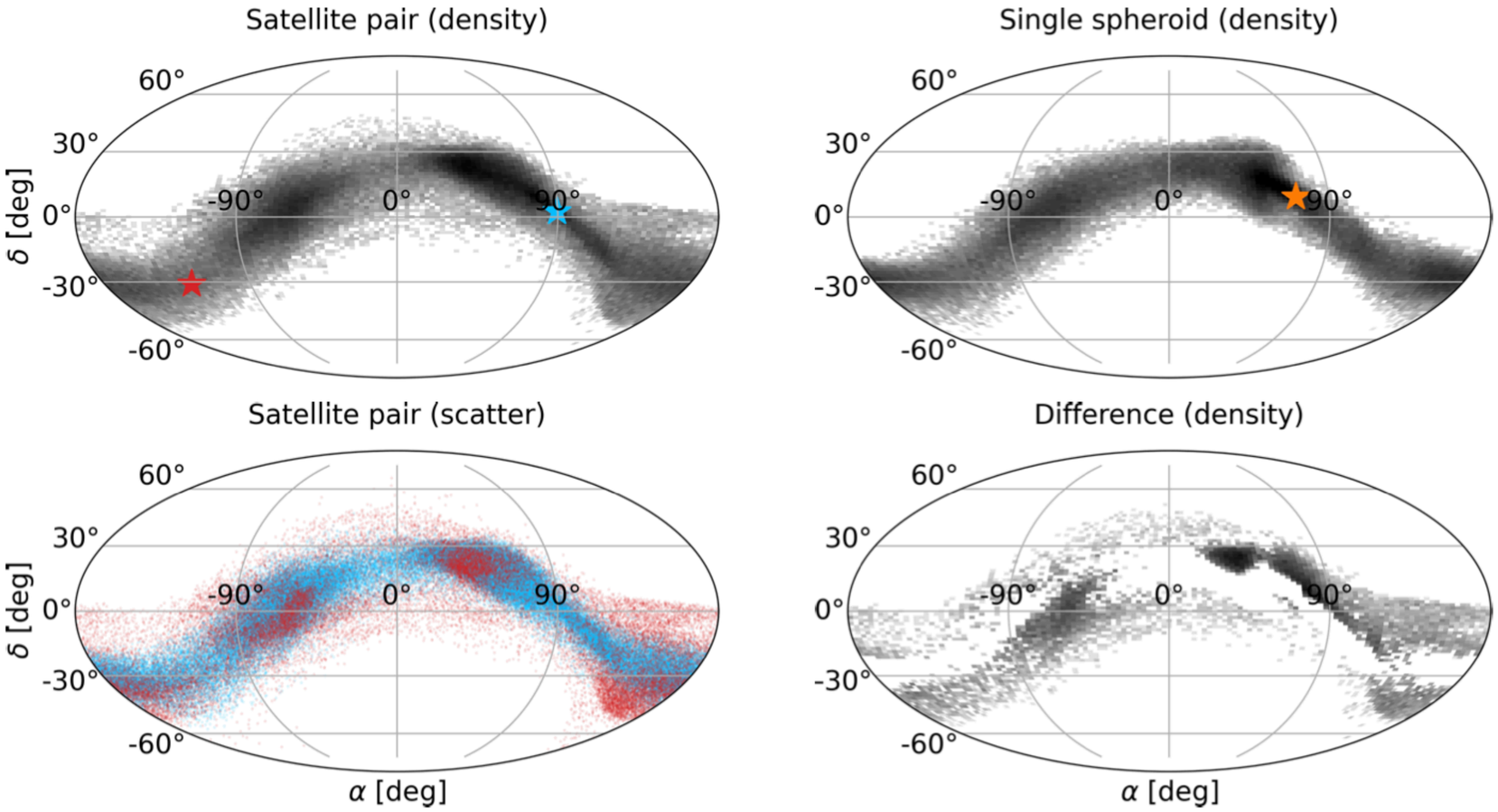
pre-infall

post-infall



EY Davies et al. (2024)

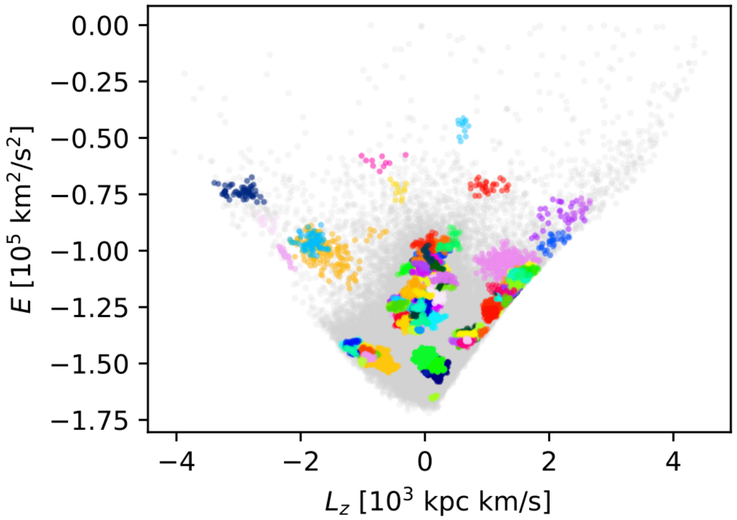
A new explanation?



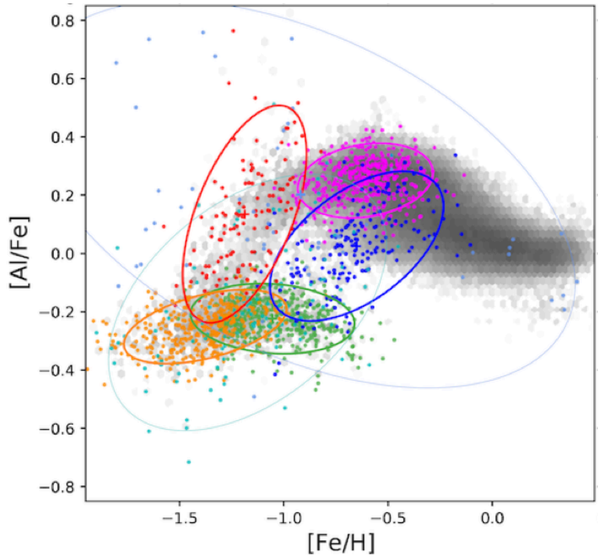
EY Davies et al. (2024)

Galactic Archaeology (a.k.a naming blobs)

- Using observatories (e.g. *Gaia*) we collect both kinematic and chemical data of stars:
- **Kinematic** — position and velocity (e.g. x, y, z, v_x, v_y, v_z)
- **Chemical** — abundance of certain elements (e.g. Fe, Al, Mg)



Credit: E Dodd et al. (2023)

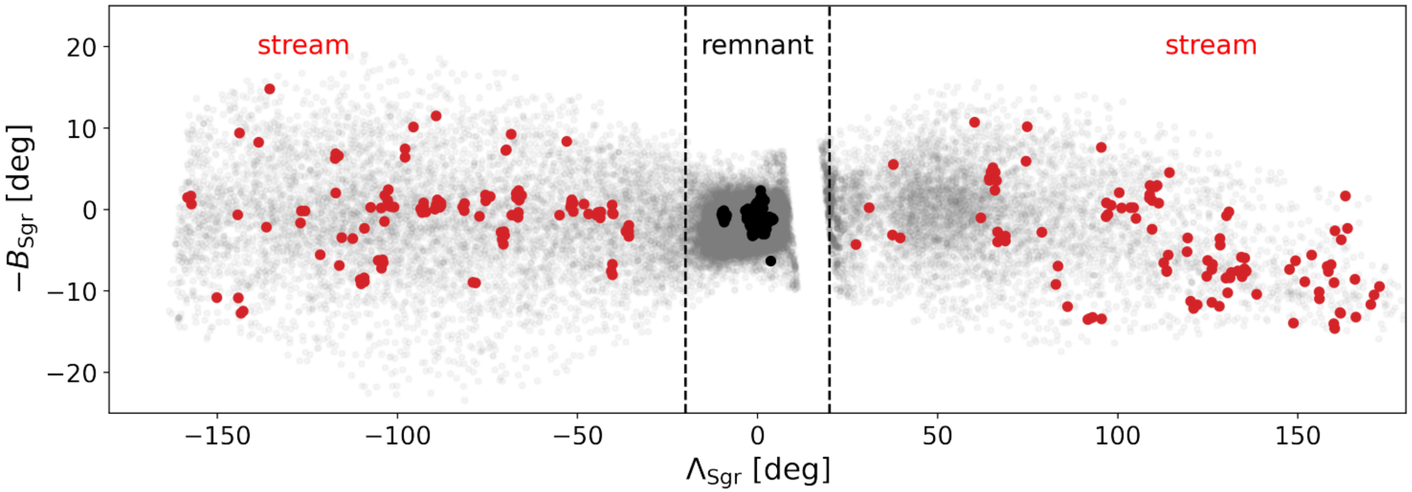


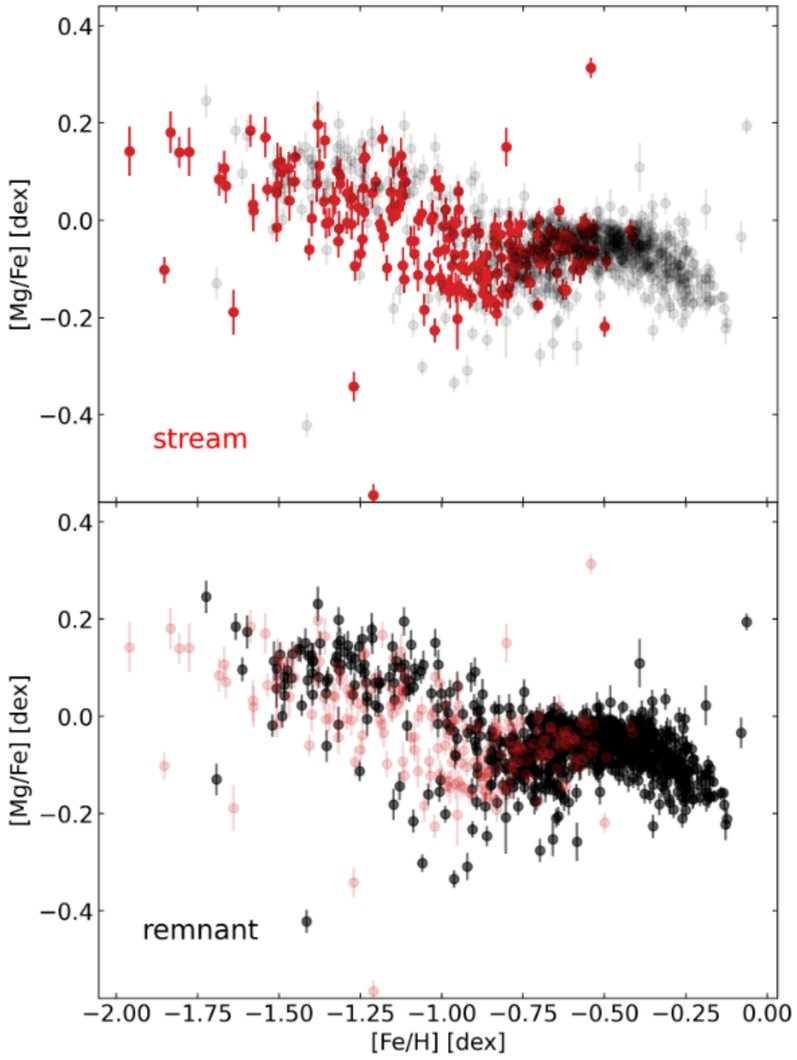
Credit: G Myeong et al. (2022)

Chemical populations of the stream

N = 224
N = 886

EY Davies et al. (2024)

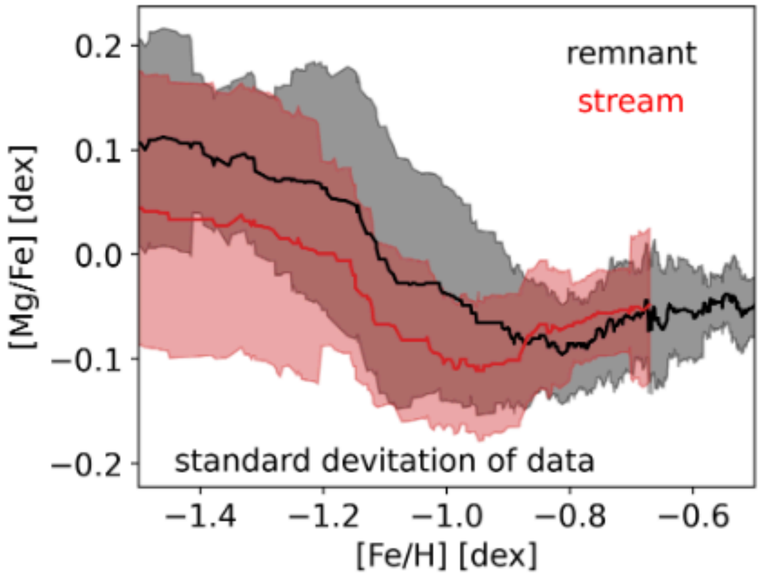


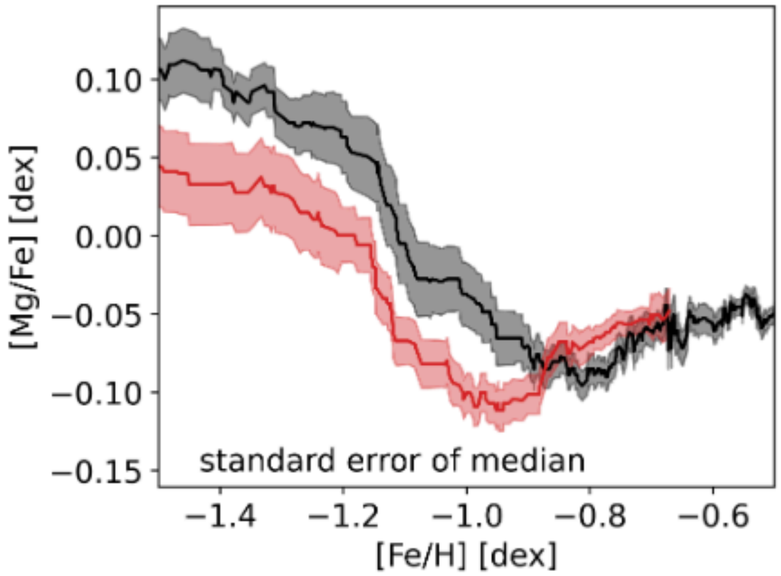


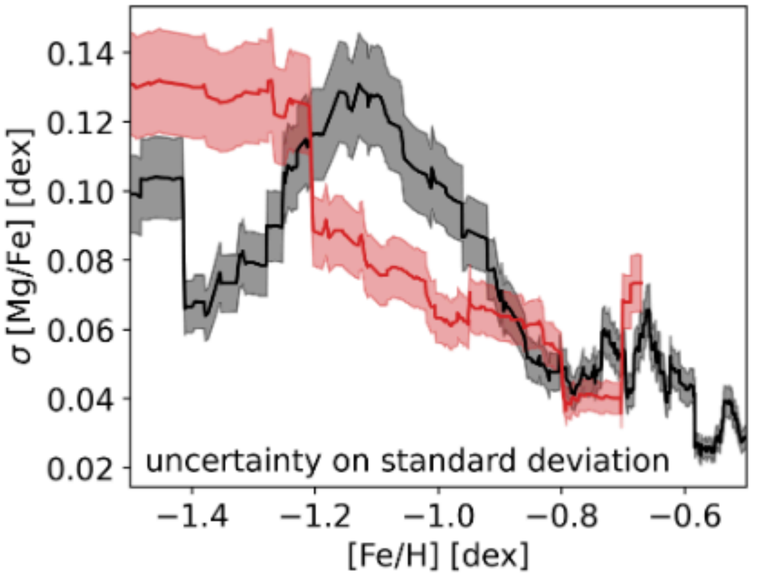
~55,000 Sagittarius stars from Vasiliev et al. (2021)
~1000 that have alpha measurements from APOGEE

Fitting tracks to the stream

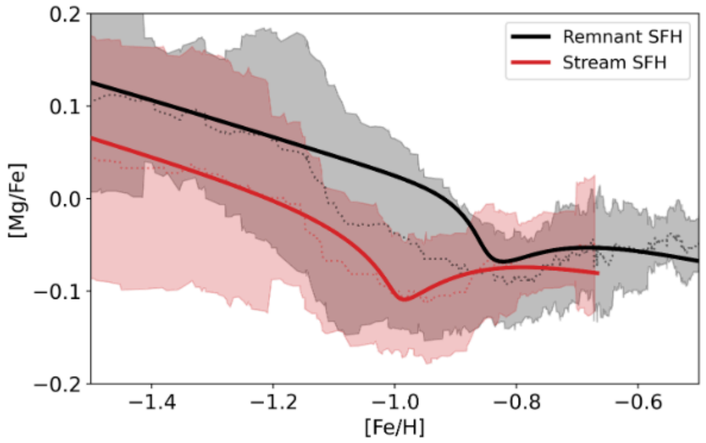
EY Davies et al. (2024)



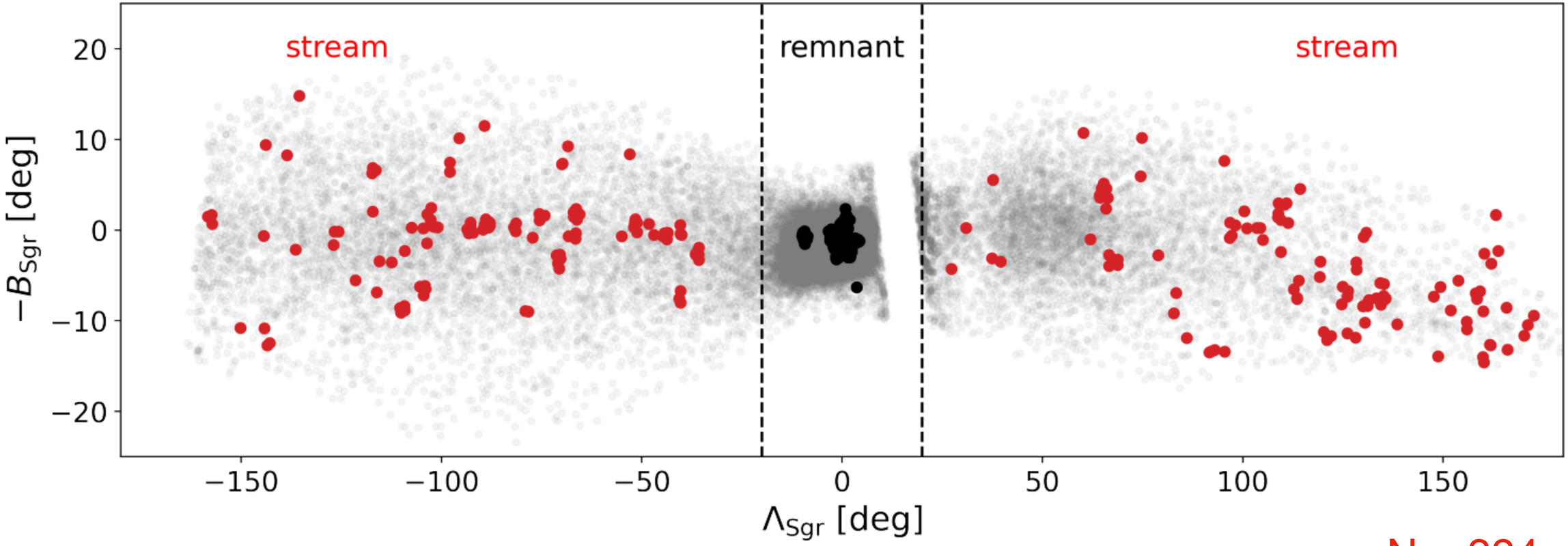




It is possible to fit unique chemical evolution models to these tracks.



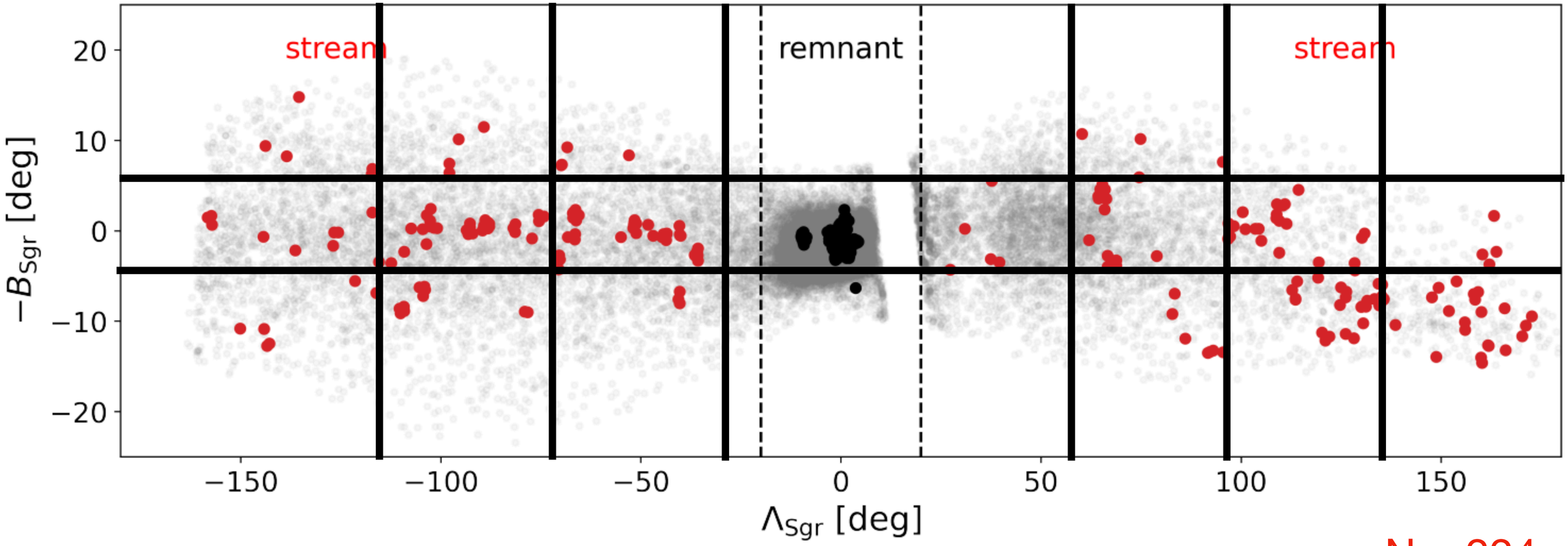
Deconstructing the Sagittarius stream



N = 224

N = 886

Deconstructing the Sagittarius stream



N = 224

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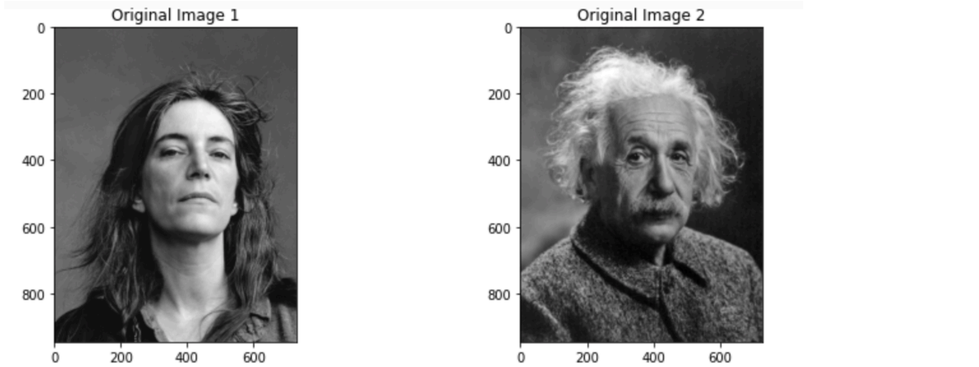
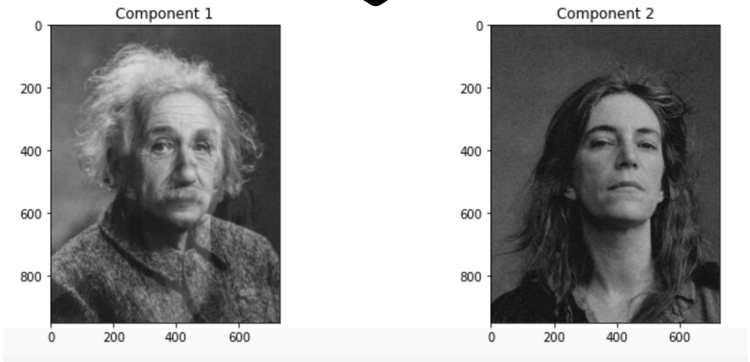
Deconstructing the Sagittarius stream

Original images



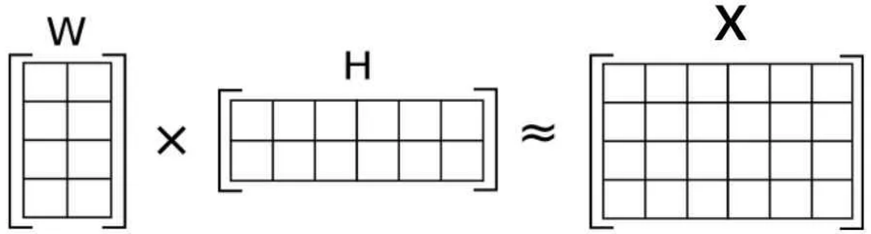
NMF*

Reconstructed images



*Non-negative matrix factorisation

Rewrite data, X, as the product of two matrices:



X = data
H = components
W = weights

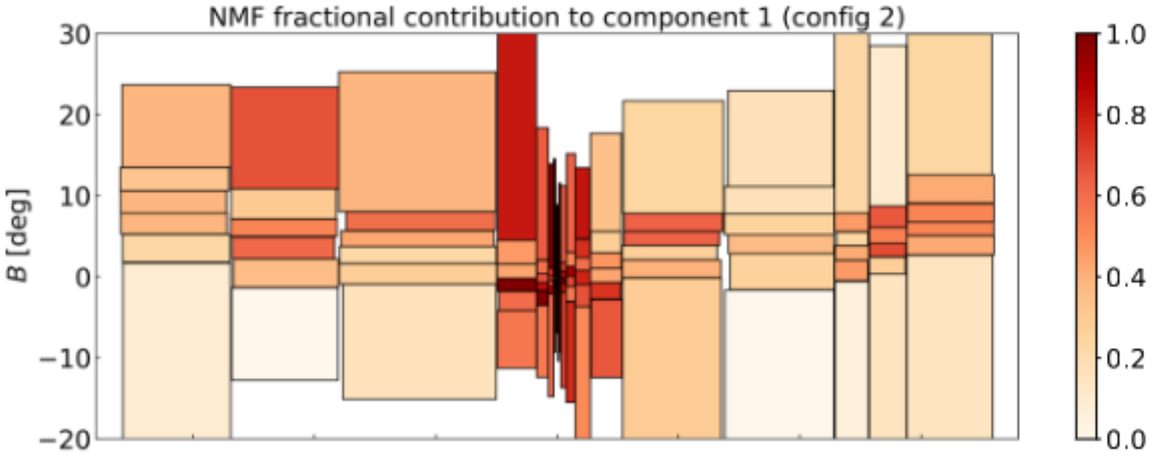
Set random initial values for W, H.

Continuously update W, H so that that the Euclidean distance is minimised:

$$||X - WH|| = \sqrt{\sum_{ij}\left(X_{ij} - \sum_{k} W_{ik}H_{kj}\right)^2}$$

Applying NMF to streams

Work in progress

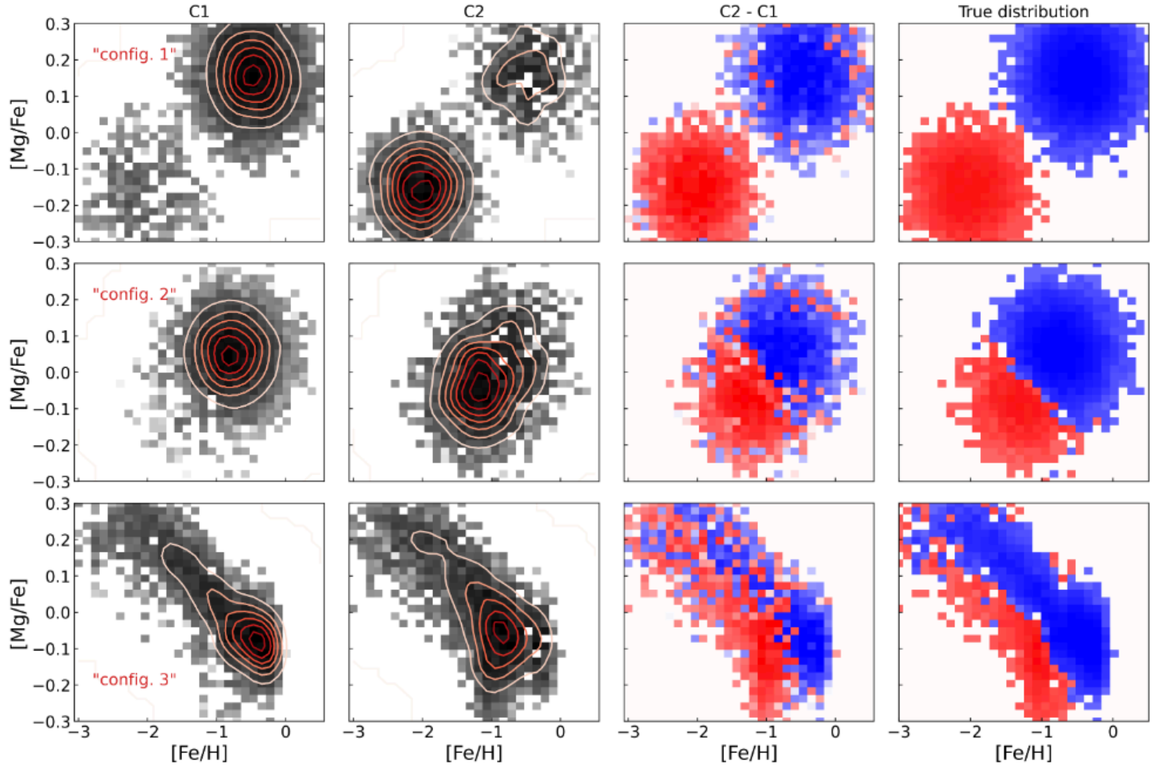


Create bins along the stream such that each bin contains an equal number of stars.

Within each bin there will be a mixture of several components.

Run NMF and see if it is able to reconstruct the populations.

Maybe run NMF on an incomplete sample?

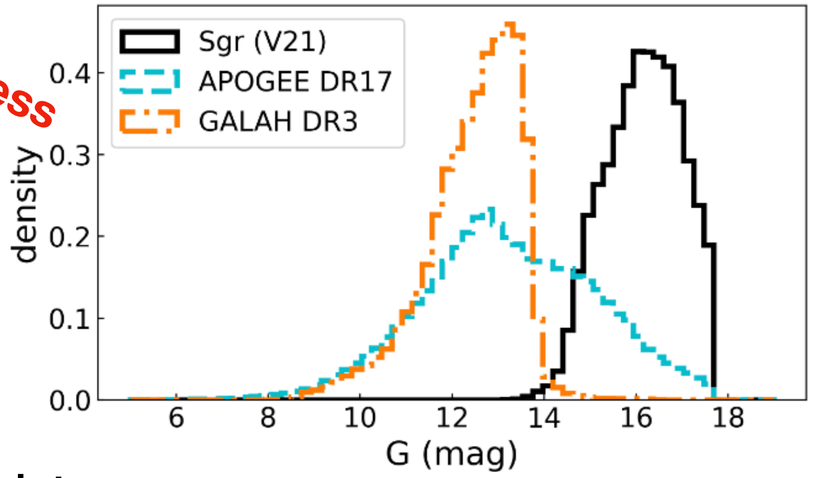


Building a sample of Sgr stars

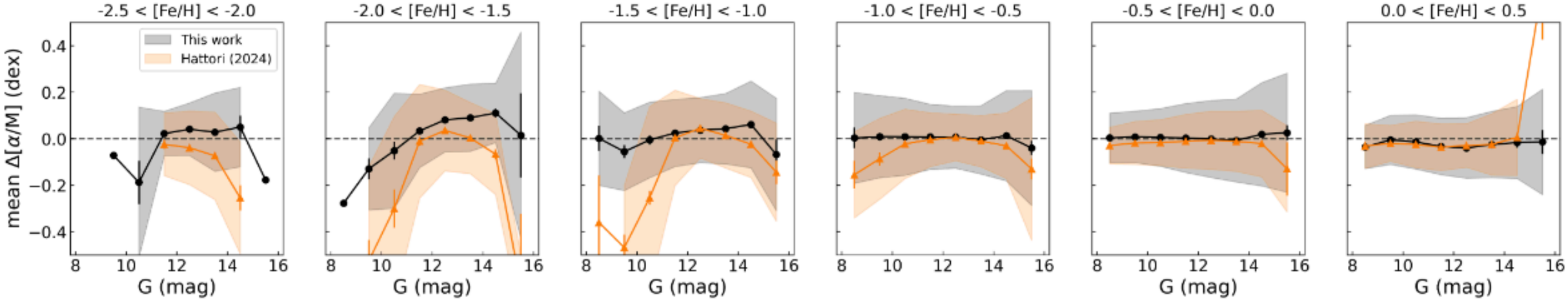
- Current only have a few hundred APOGEE stars with chemical information
- There have been many examples of trying to machine-learn stellar parameters (and some alpha abundances)…
  - Andrae et al. (2023) - XGBoost
  - Hattori (2024) - Quantile Random Forest
  - Fallows & Sanders (2024) - Uncertain Neural Network
  - Li et al. (2023) - AspGap

Building a sample of Sgr stars

Work in progress

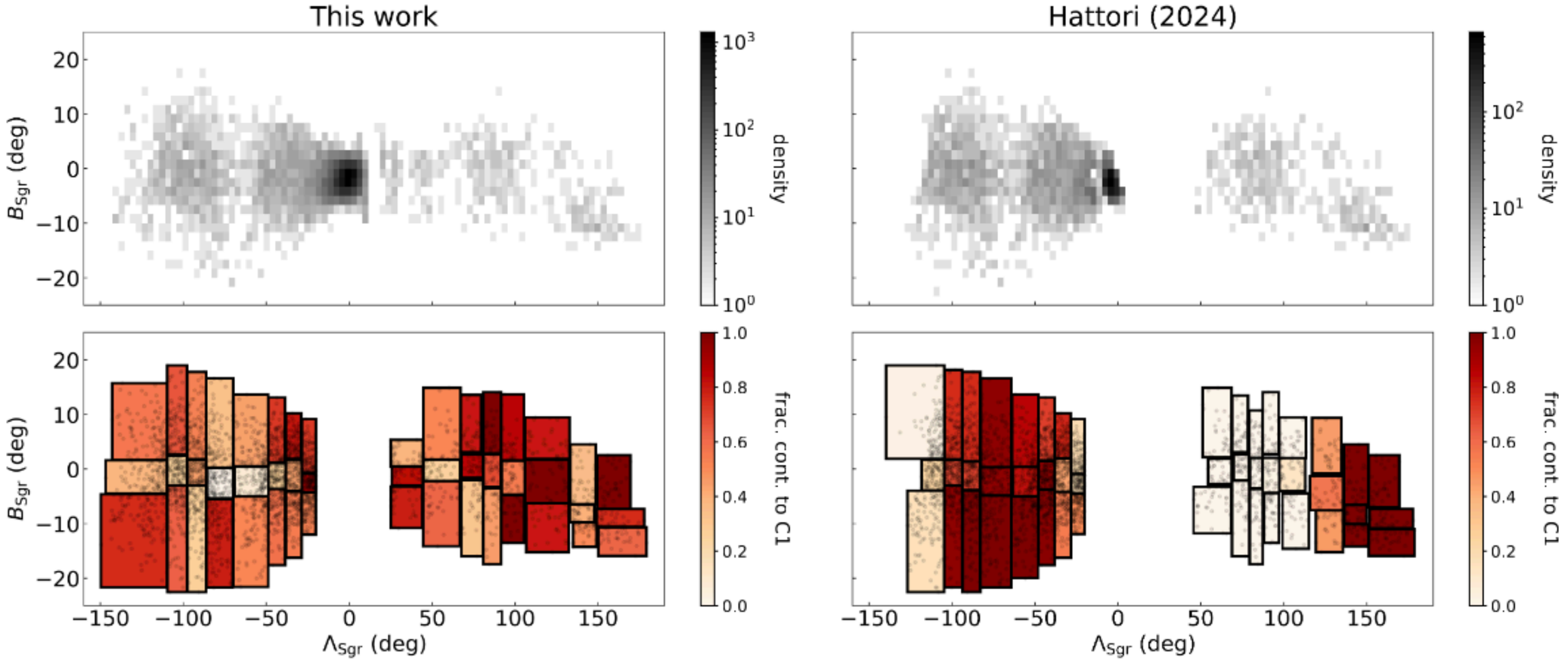


- Many samples show a bias with respect to brightness
- Crucial for the Sgr stars which are mostly very low brightness
- We are in the process of building our own sample (originally applied crude calibration, now working on training a neural network)



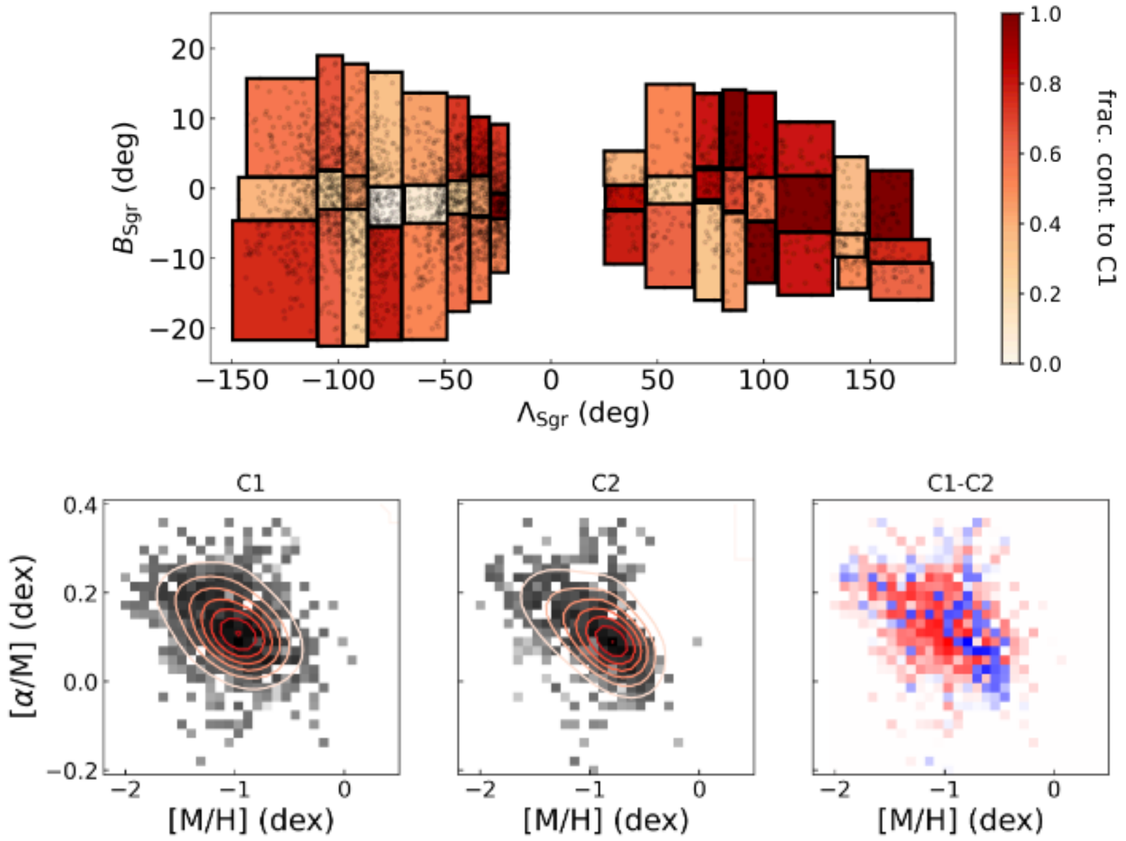
Deconstructing the Sagittarius stream

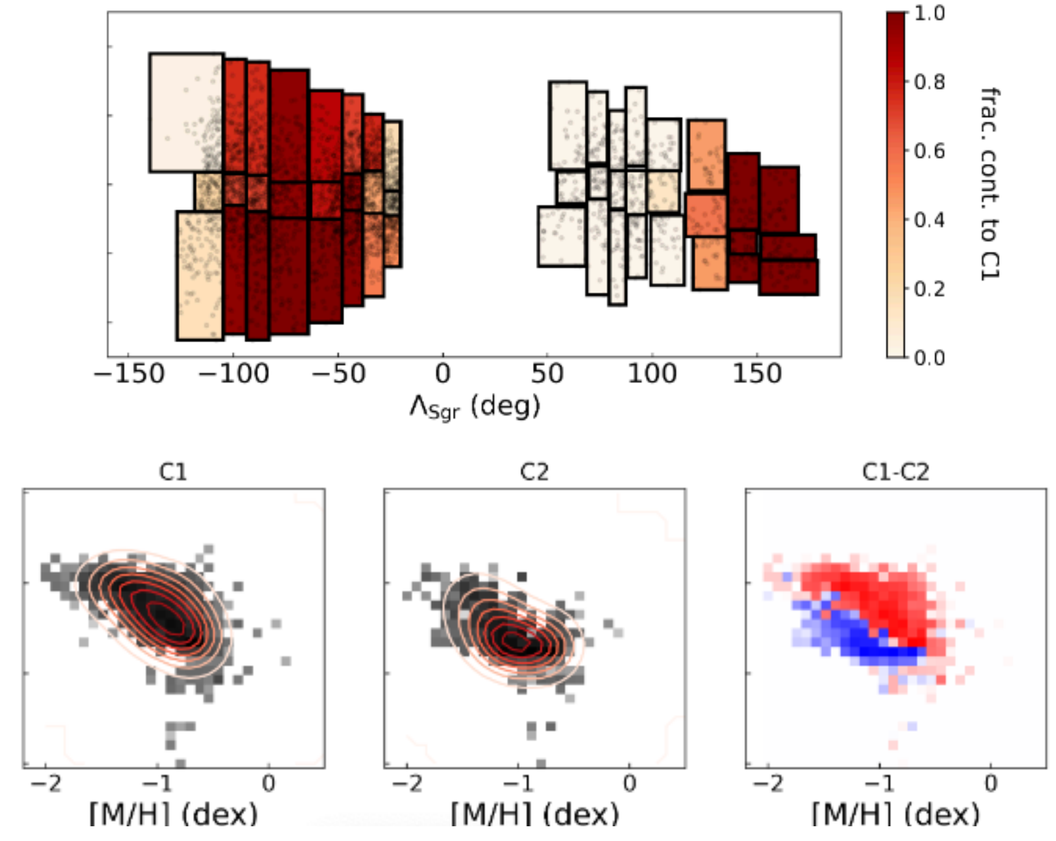
Apply the NMF to data.
Brightness effect appears to be removed.



Deconstructing the Sagittarius stream

Compare the reconstructed components.





Thanks for listening!

Questions?

Summary:

- There are unexplained features in Sgr
- Some evidence for two chemical populations
- We are developing a method to disentangle these populations
- Improved data of Sgr star chemistry is needed

Please talk to me if I can use your cosmological simulations, or if you have advice regarding measurements from XP spectra (or other ML tips!)

Relevant papers:

EY Davies et al. (2024a) - arXiv:2308.01958

EY Davies et al. (2024b) - arXiv:2312.08424