Using Machine Learning to Catalog Accreted Stars in ESA Gaia DR3 Survey.

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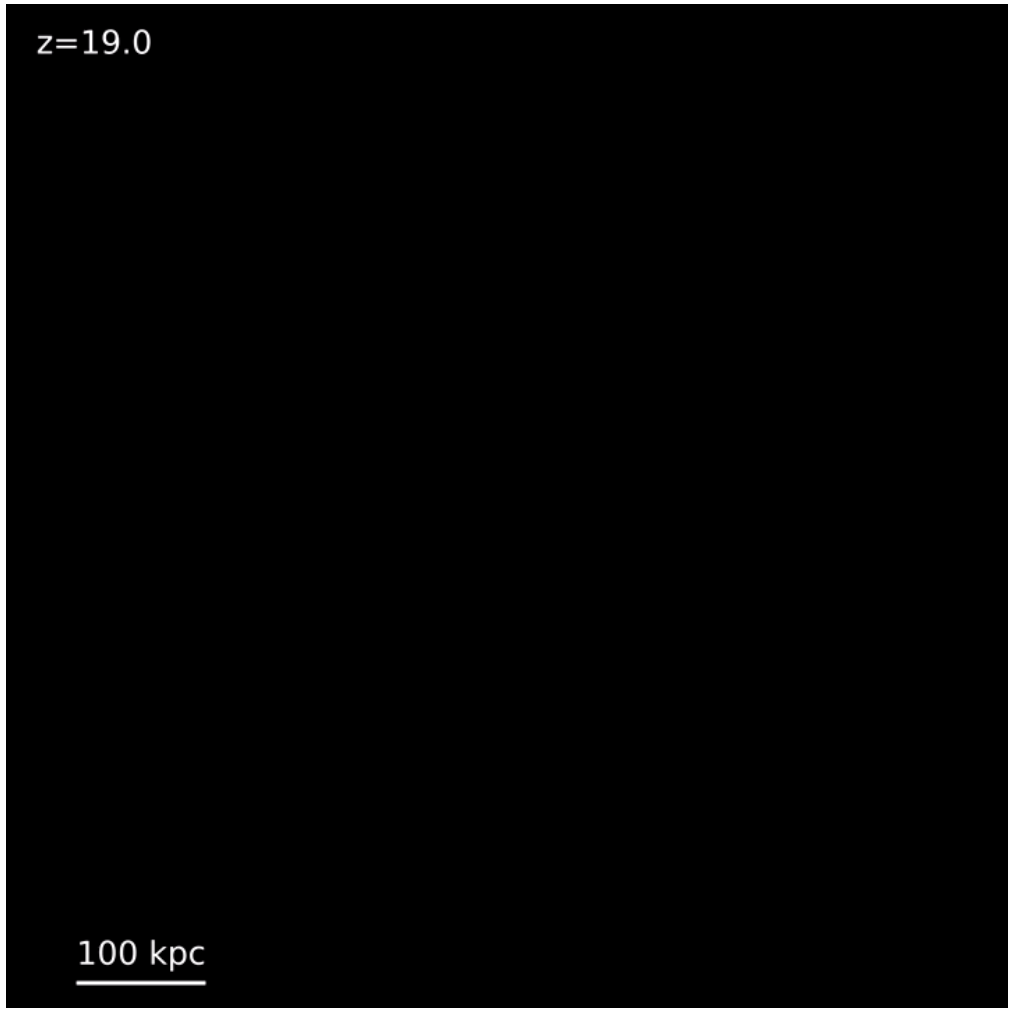
Background

- In situ stars:
  - born within the Milky Way
- Accreted stars:
  - merged with the Milky Way



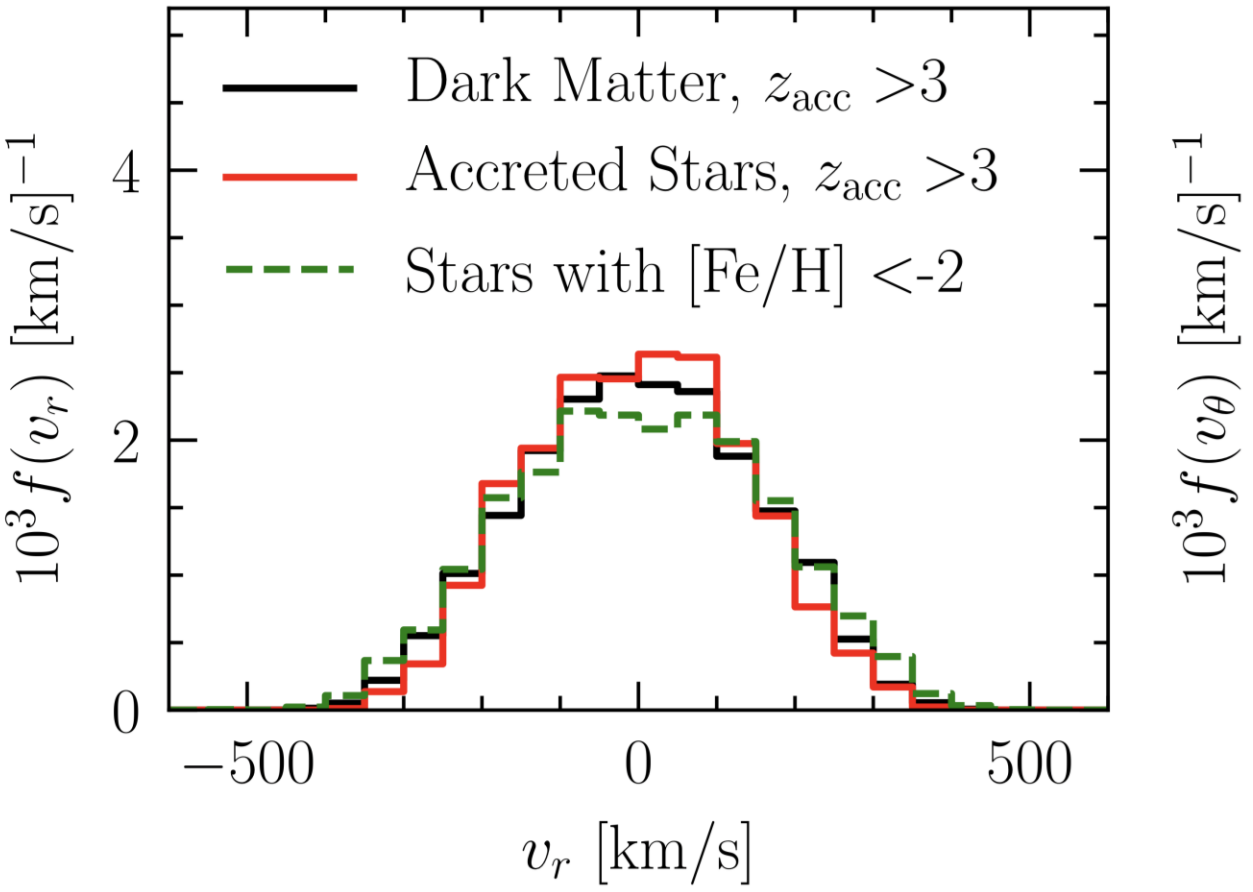
Latte simulation (m12i): formation over 13.8 billion years showing stars

Objective

- To distinguish which stars of the Milky Way are accreted based on Gaia DR3 Survey.

Motivation

Dark matter shares similar kinematics information to accreted stars.



L. Necib et al., The Astrophysical Journal 883, 27 (2019).

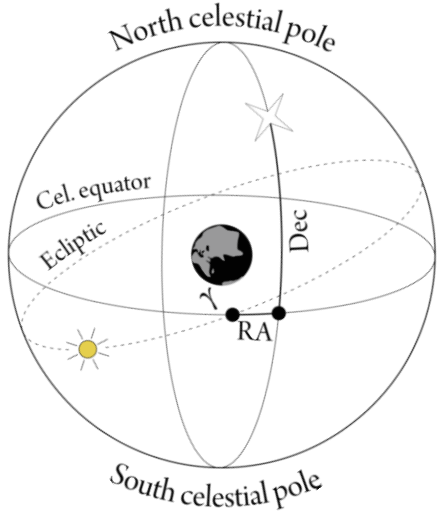
Coordinate Systems

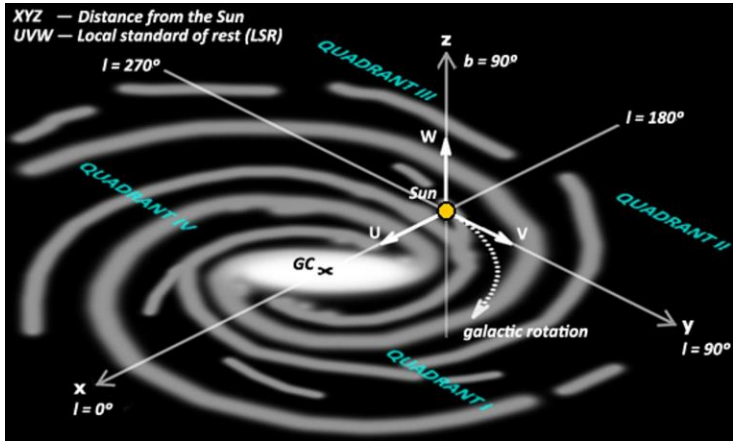
Equatorial:

l, b, pmra, pmdec, parallax, radial velocities...

Galactocentric:

x, y, z, Vx, Vy, Vz...



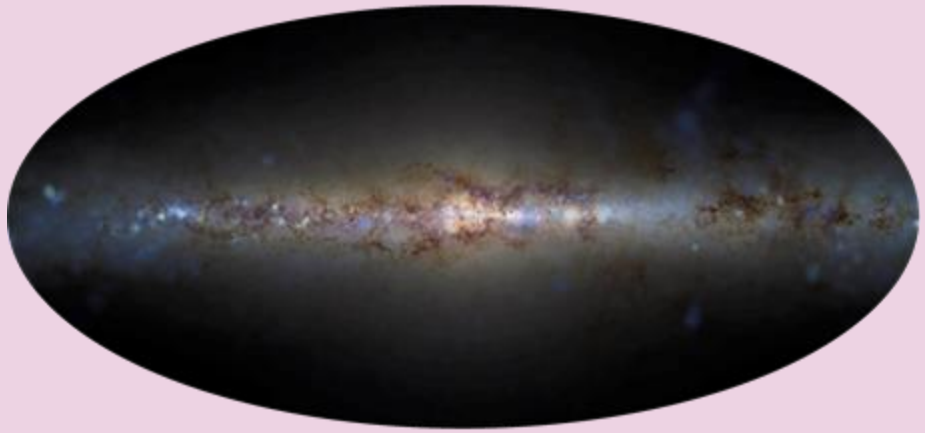


Gaia ESA Data Release 3 (DR3)

- Release on June 13, 2022.
- Abundant radial velocity measurements.
- Well measured parallax.

Ananke Simulations based on FIRE

Ananke DR2 m12i:



FIRE Simulation Group

Gaia DR2:

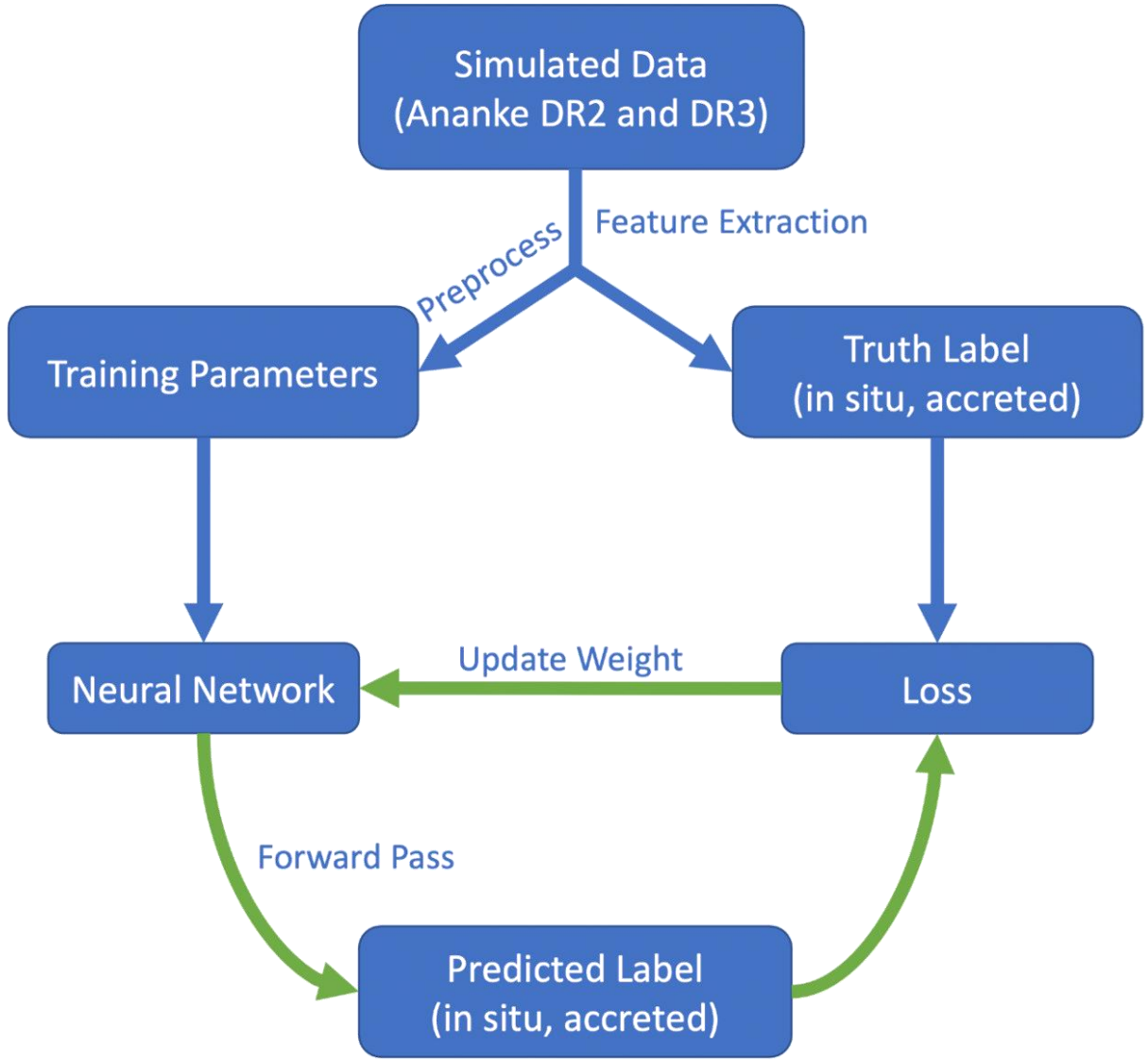
Gaia collaboration et al. (2016, 2018)

Simulation Data:

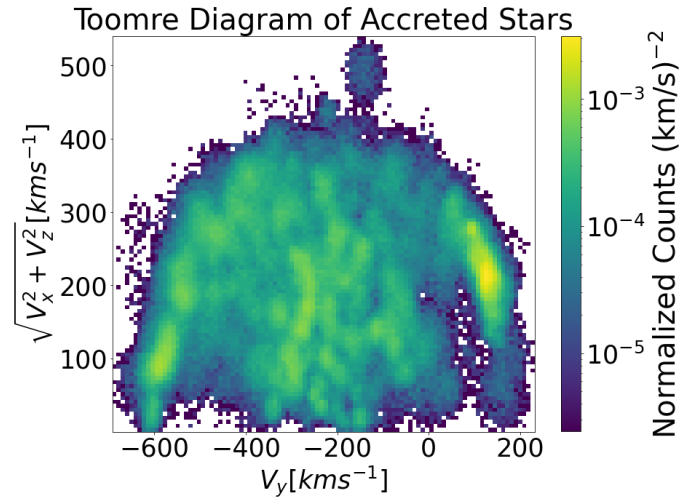
Ananke DR2 m12i lsr0

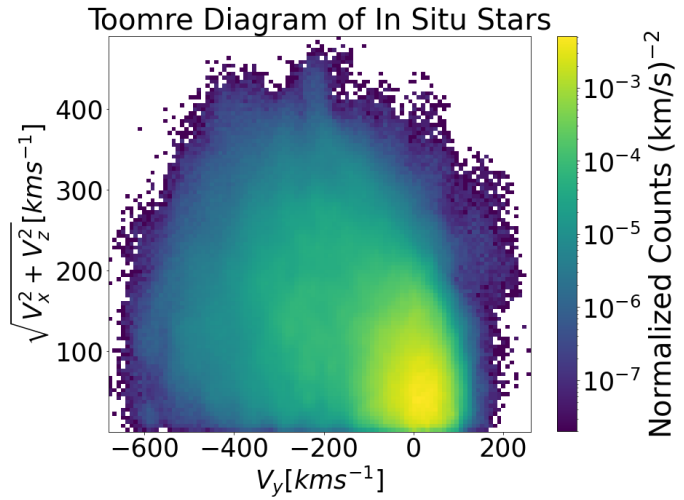
Ananke DR3 m12i lsr0

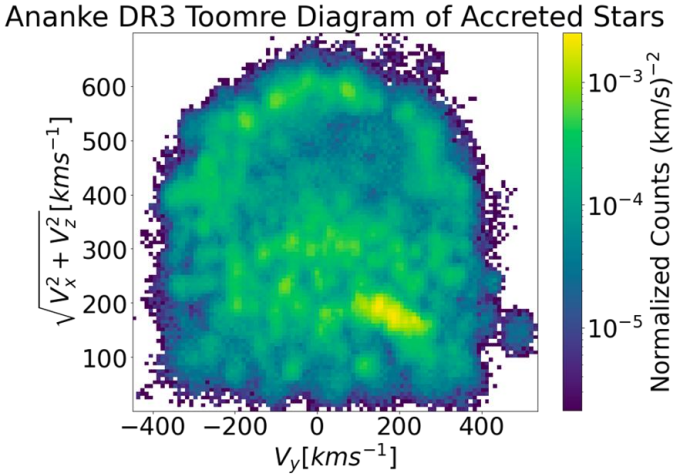
Machine Learning Algorithms

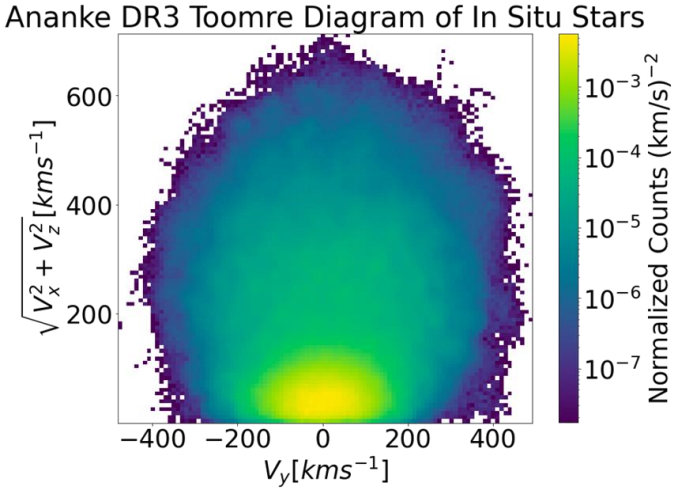


In situ and accreted stars have distinctive velocity distributions.

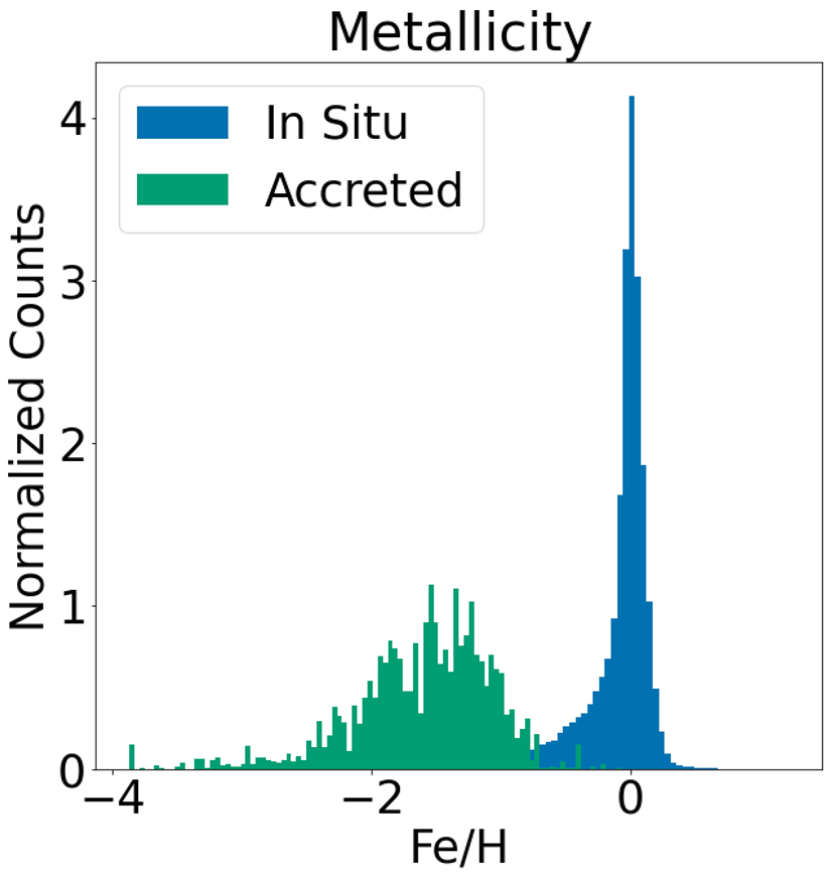


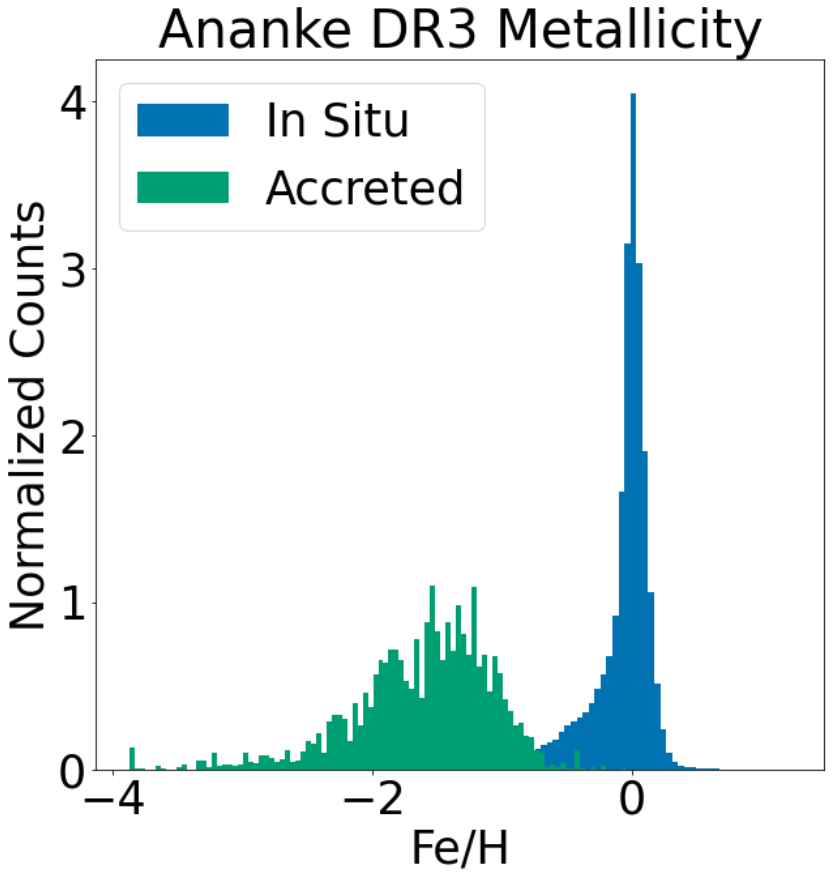






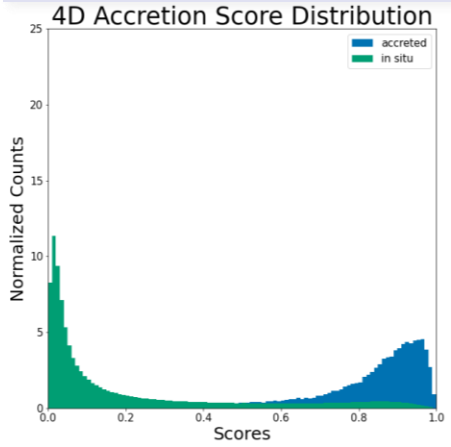
Different metallicity

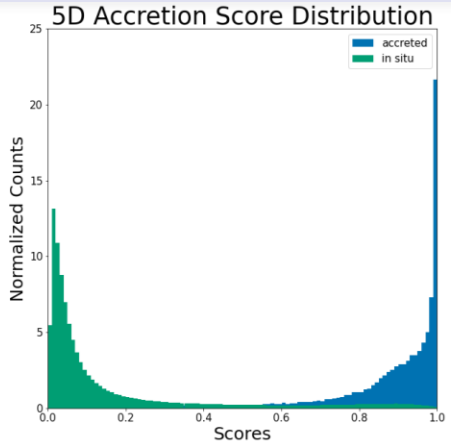


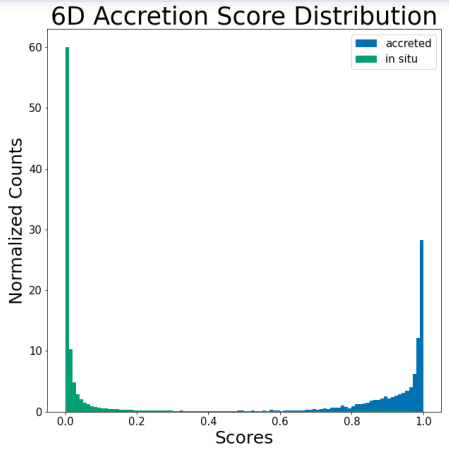


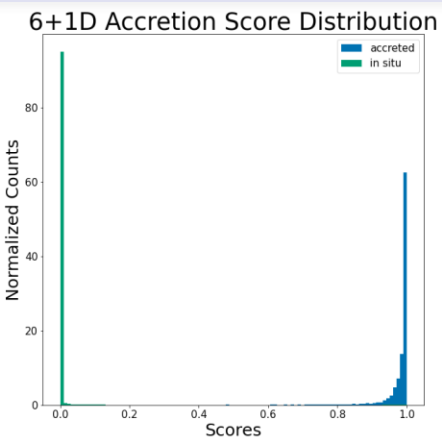
Better score separations with more dimensions.

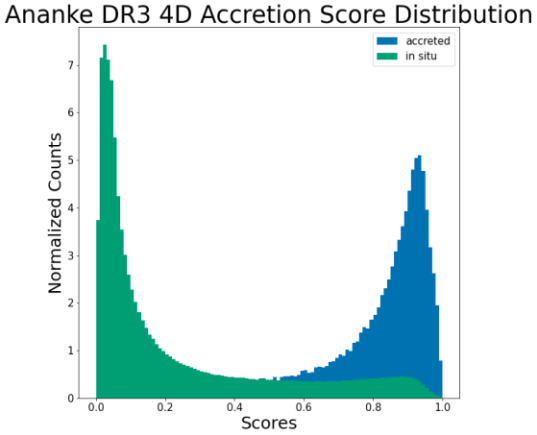
$$\text{score} = \frac{e^{\text{accreted}}}{e^{\text{accreted}} + e^{\text{in situ}}}$$

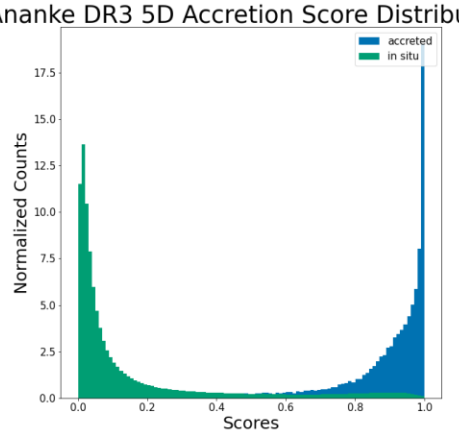


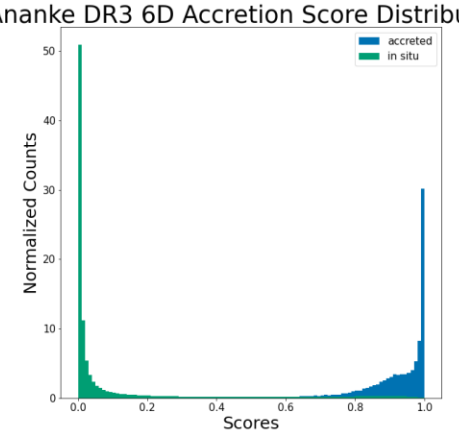


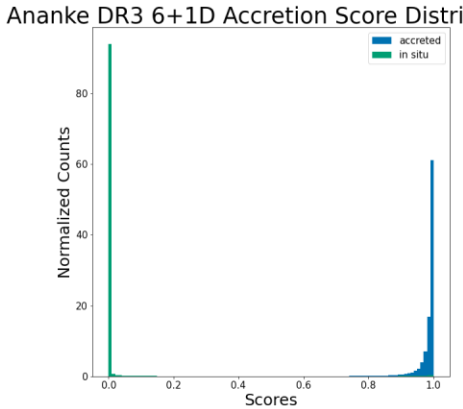




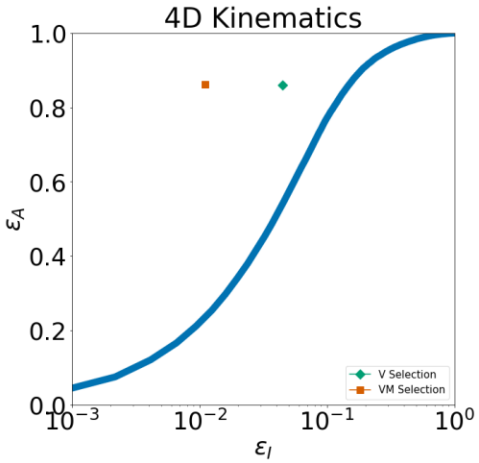


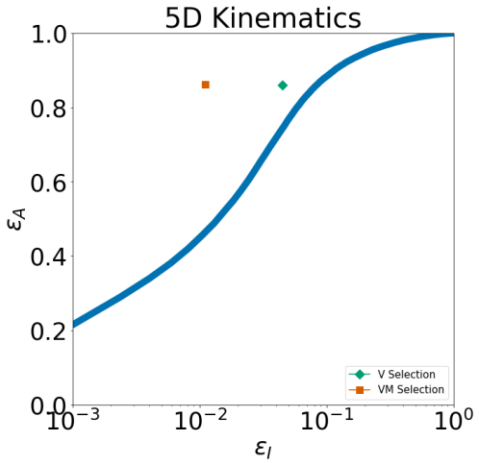


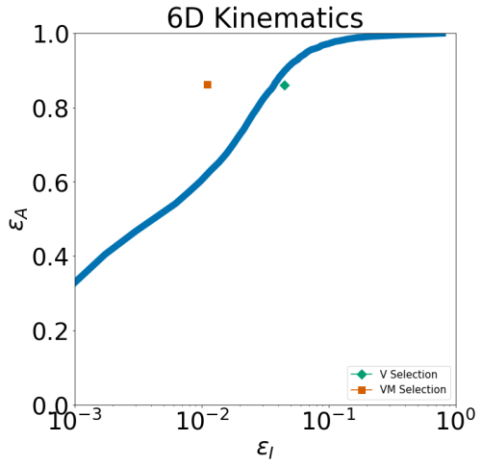


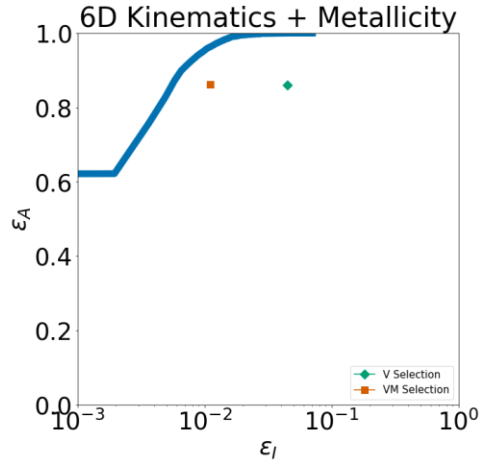


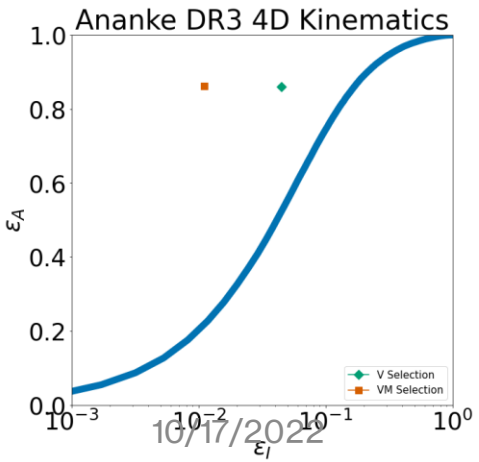
Better performance with more dimensions.

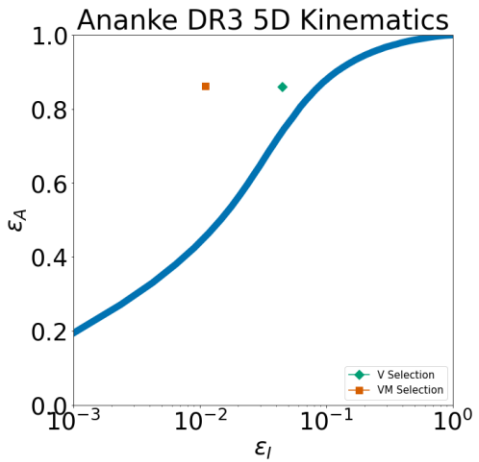


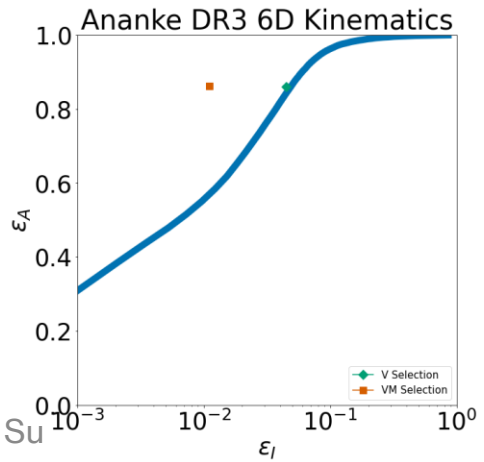


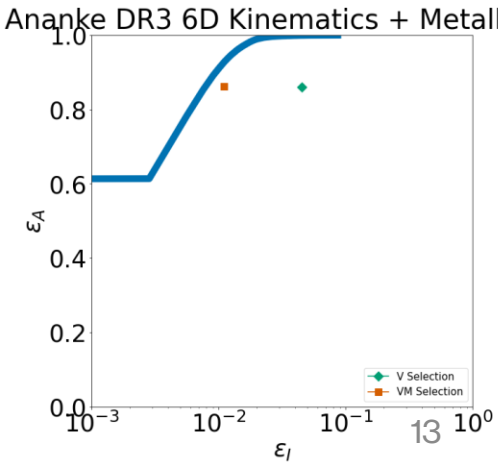












Next steps

- Including action angle variables for training
- Transfer learning to Ananke DR3 m12f lsr0
- Coordinate transformation from equatorial to cartesian
- Gaia DR3 Accretion Catalog
- Even bigger picture: Dark Matter Map

Main References

Gaia DR2 Accretion Catalog:

- Ostdiek, Necib et al. (2019).
- Helmi et al. (2020).

Gaia data:

- Gaia collaboration et al. (2016, 2018, 2022)

FIRE Simulations:

- Hopkins et al. (2013, 2015)
- Wetzel et al. (2016)
- Sanderson et al. (2020)

Main Takeaways + Q & A

The Milky Way experienced a hierarchical structure formation.

We use the simulated galaxy data to train our neural networks.

The accretion catalog can help map out dark matter.