

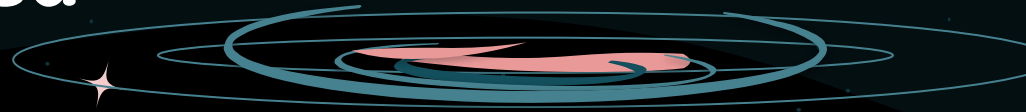
Modelling the Last Major Merger that Shaped Milky Way

Istiak Akib

PhD 2nd year

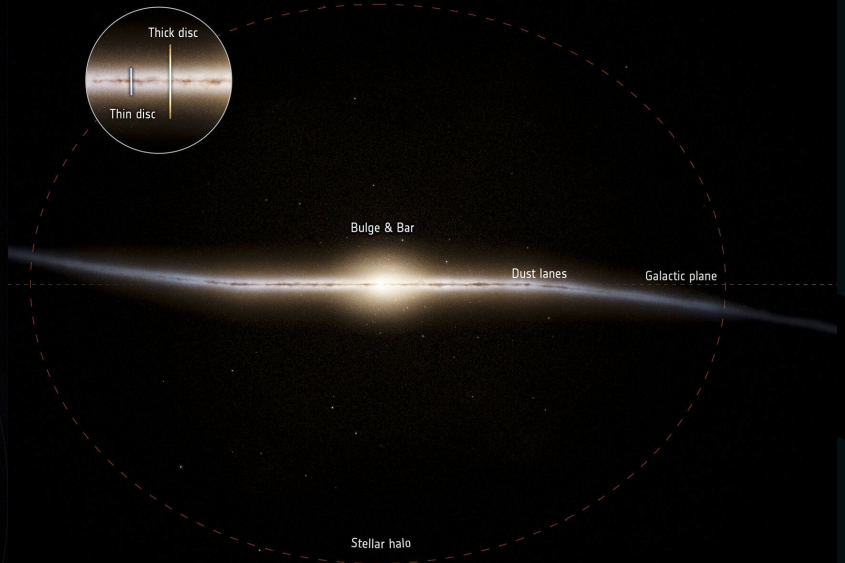
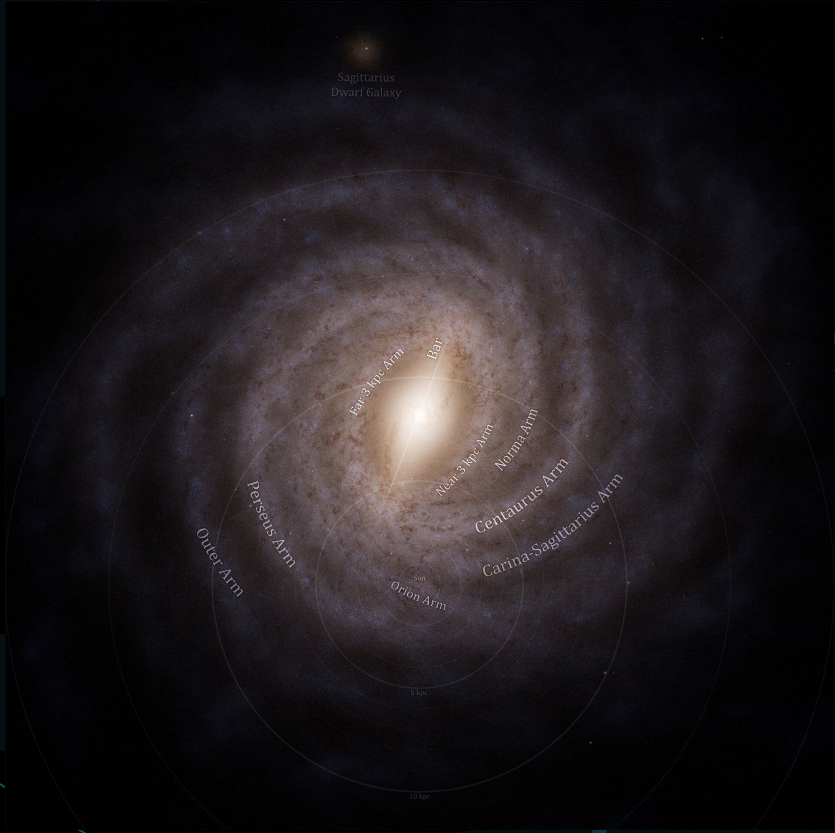
LIRA, Observatoire de Paris

Supervisors: Francois Hammer and Yanbin Yang





What is the Milky Way?



What is the Milky Way?

Bar/Bulge: $1.4\sim 1.7 \times 10^{10} M_{\text{sun}}$
bar half length 3~5 kpc
bar rotation $30\sim 40 \text{ kms}^{-1} \text{ kpc}^{-1}$

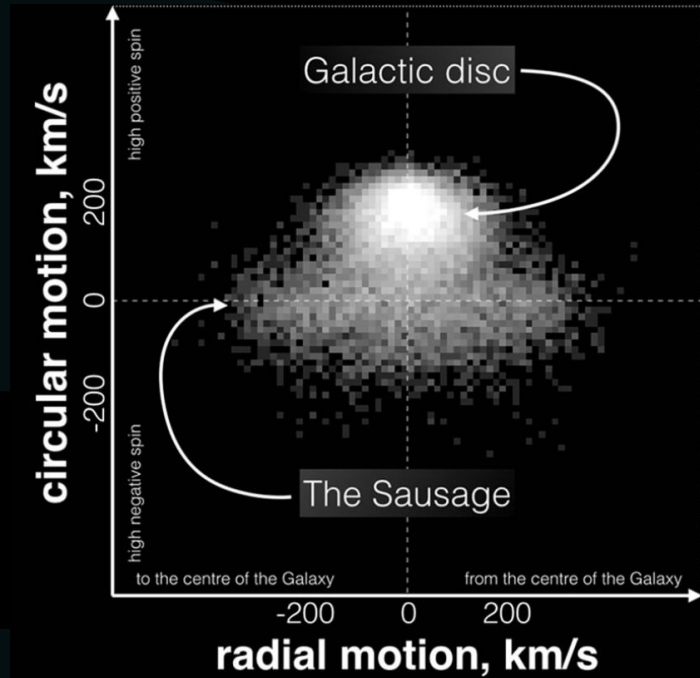
Disk: $4\sim 5 \times 10^{10} M_{\text{sun}}$
Thick to thin ratio ~1:1 (mass) to ~1:5 (light)
Thick disk: h_r 2~2.5 kpc; h_z 0.6~0.9 kpc
Thin disk: h_r 2~3.5 kpc; h_z 0.2~0.3 kpc

Arm: 4 arms

Rotation Curve (Dark Matter)

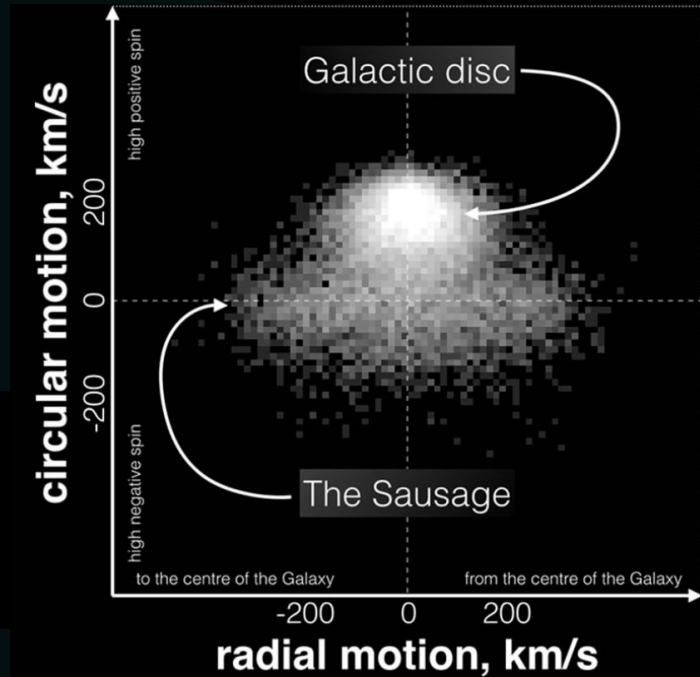
Hunt & Vasiliev 2025,
Bland-Hawthorn & Gerhard 2016

GSE (Gaia Sausage Enceladus) Merger

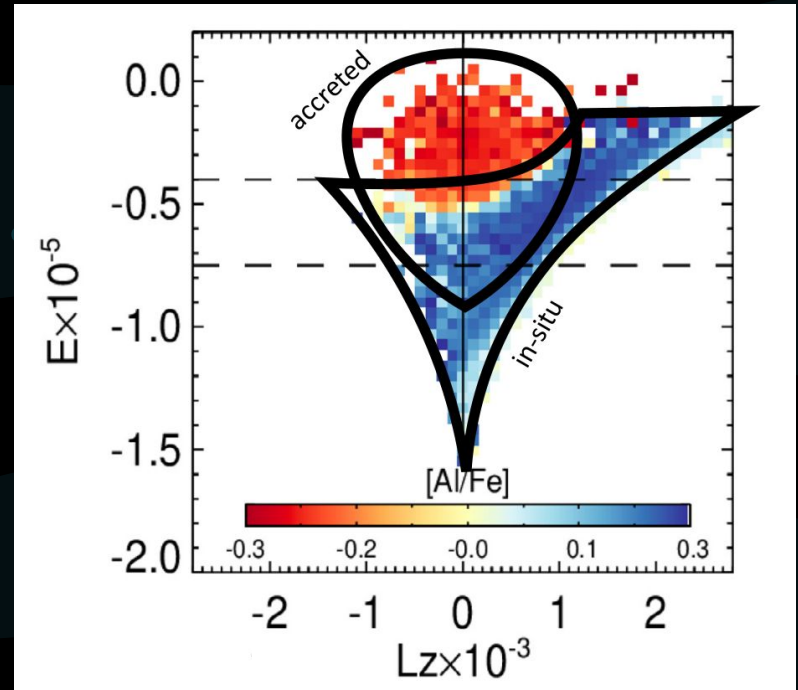


GSE, adapted from Belokurov + 2018

GSE (Gaia Sausage Enceladus) features

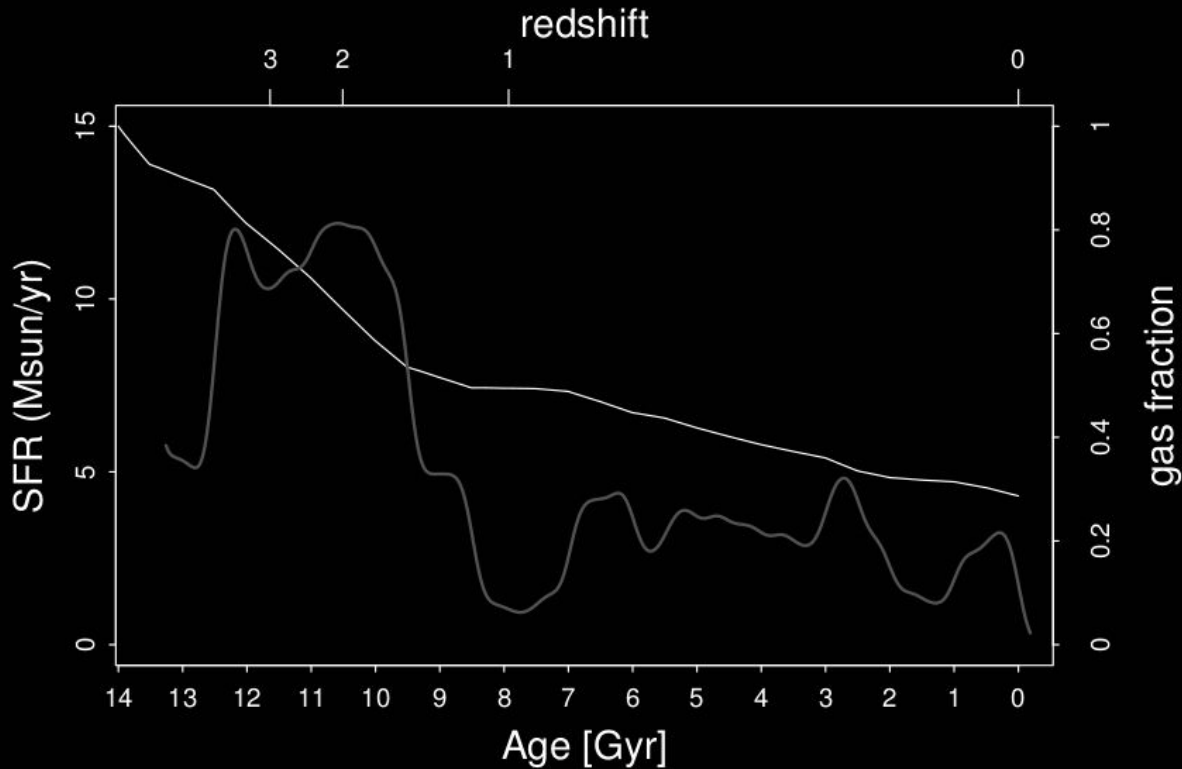


GSE, adapted from Belokurov + 2018



GSE, from Belokurov and Kravtsov (2022)

Star Formation History



MW Star Formation: Haywood et al. 2016



MW-GSE Merger Modeling

Base model: Sauvaget et al. 2018

Starting time: 12-13 Gyr ago

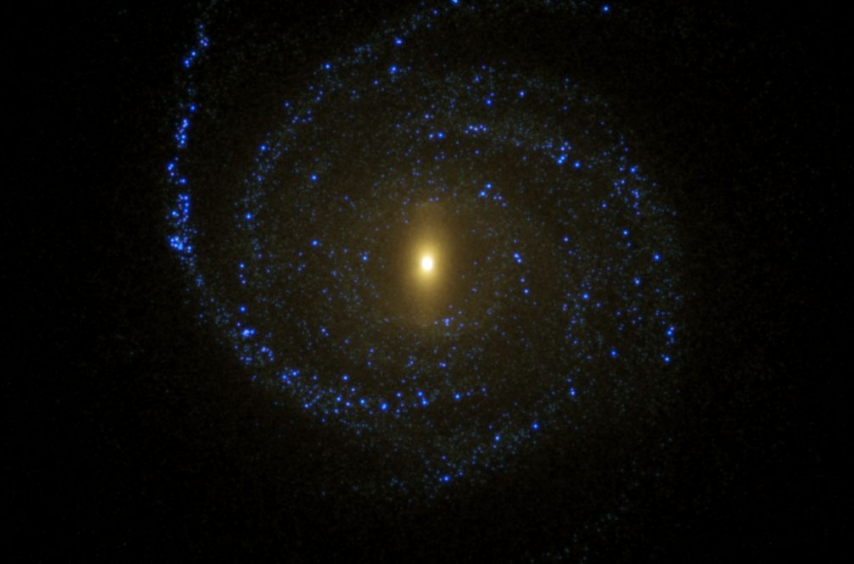
Software: GIZMO

Important variables to control:

1. Mass ratio (1:3 to 1:5)
2. Total mass ($2 \times 10^{11} \sim 9 \times 10^{11} M_{\text{sun}}$)
3. Gas fraction (75% to 95% of baryon)
4. Dark matter fraction (70% to 90%)
5. Scale lengths (Star, Gas, Dark Matter)
6. Orbit (pericenter)
7. Feedback

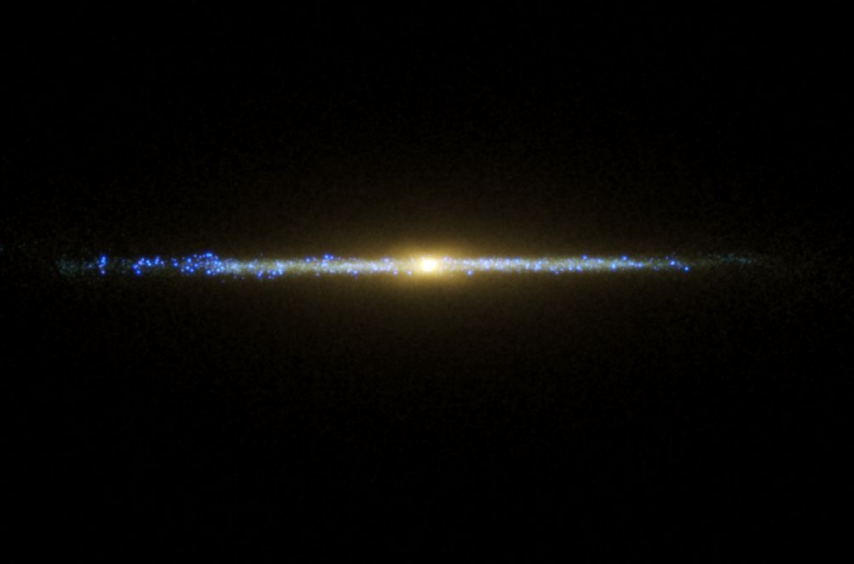
Image

TSIPRf4_21
T= 12.712 Gyr
Field= 67 x 50 sq kpc



snapshot_1300

TSIPRf4_21
T= 12.712 Gyr
Field= 67 x 50 sq kpc

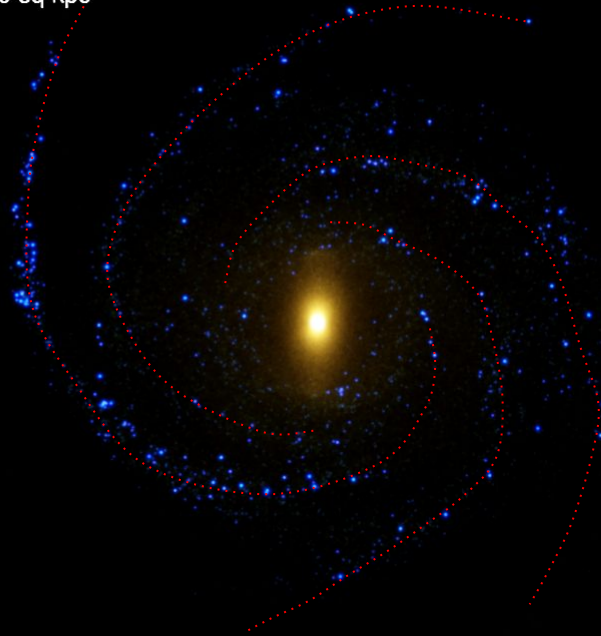


snapshot_1300

Arms

Clearer view of 4
arms with high
brightness and
contrast

TSIPRf4_21
T= 12.712 Gyr
Field= 67 x 50 sq kpc

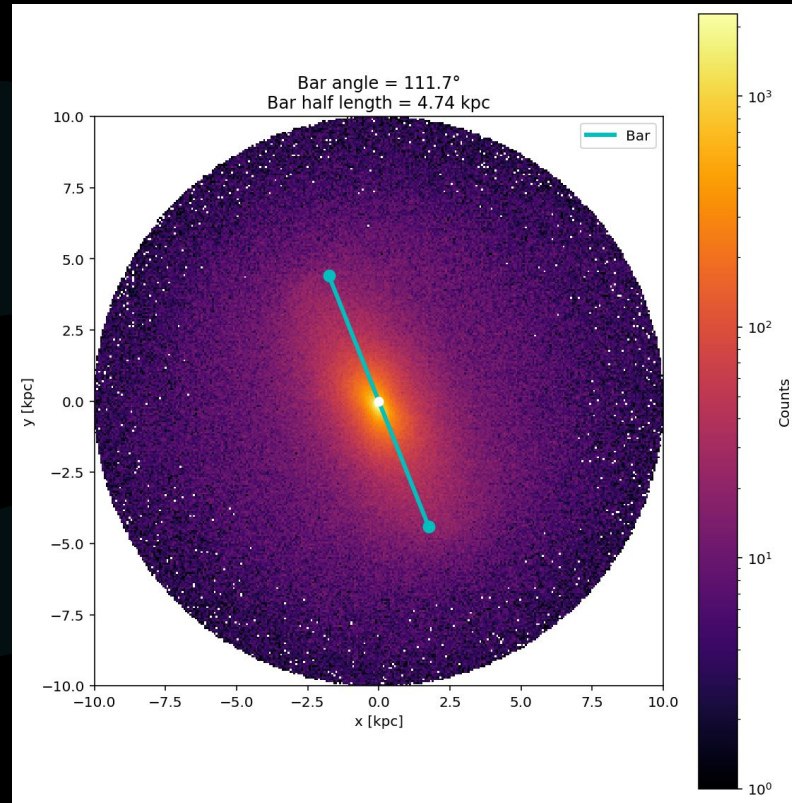


snapshot_1300

Bar

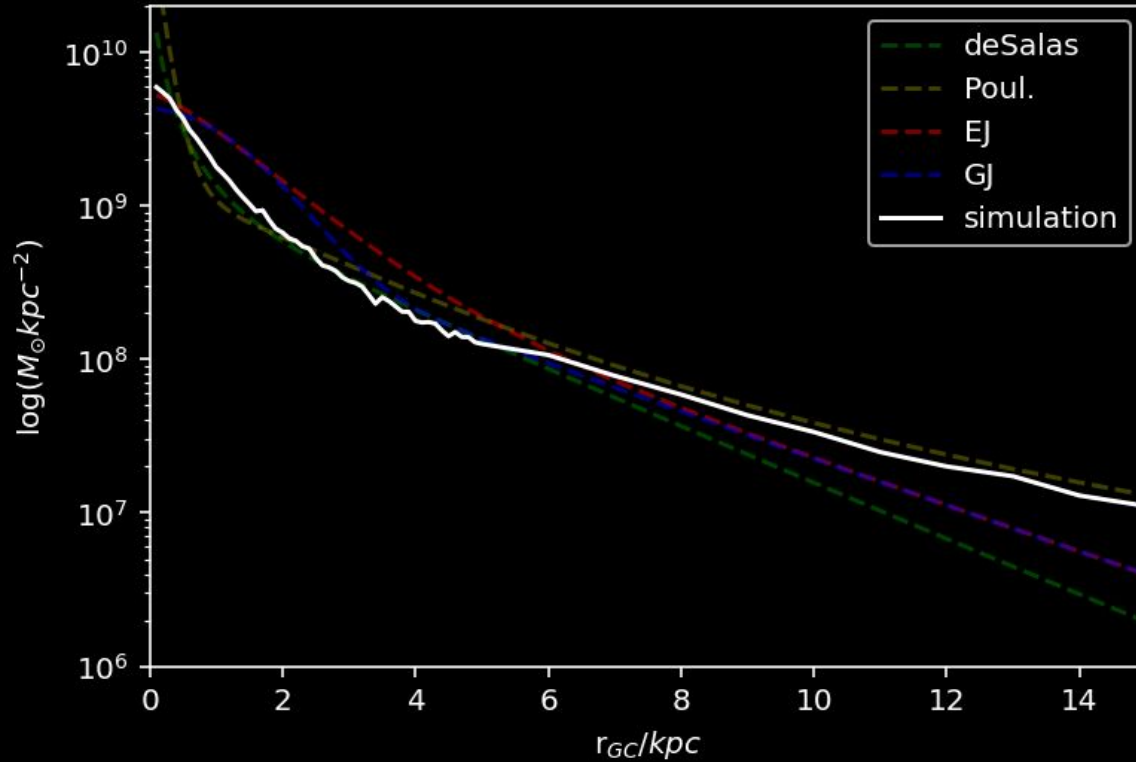
The bar has right size and rotation

Bar pattern speed for this model: 36 km/s/kpc

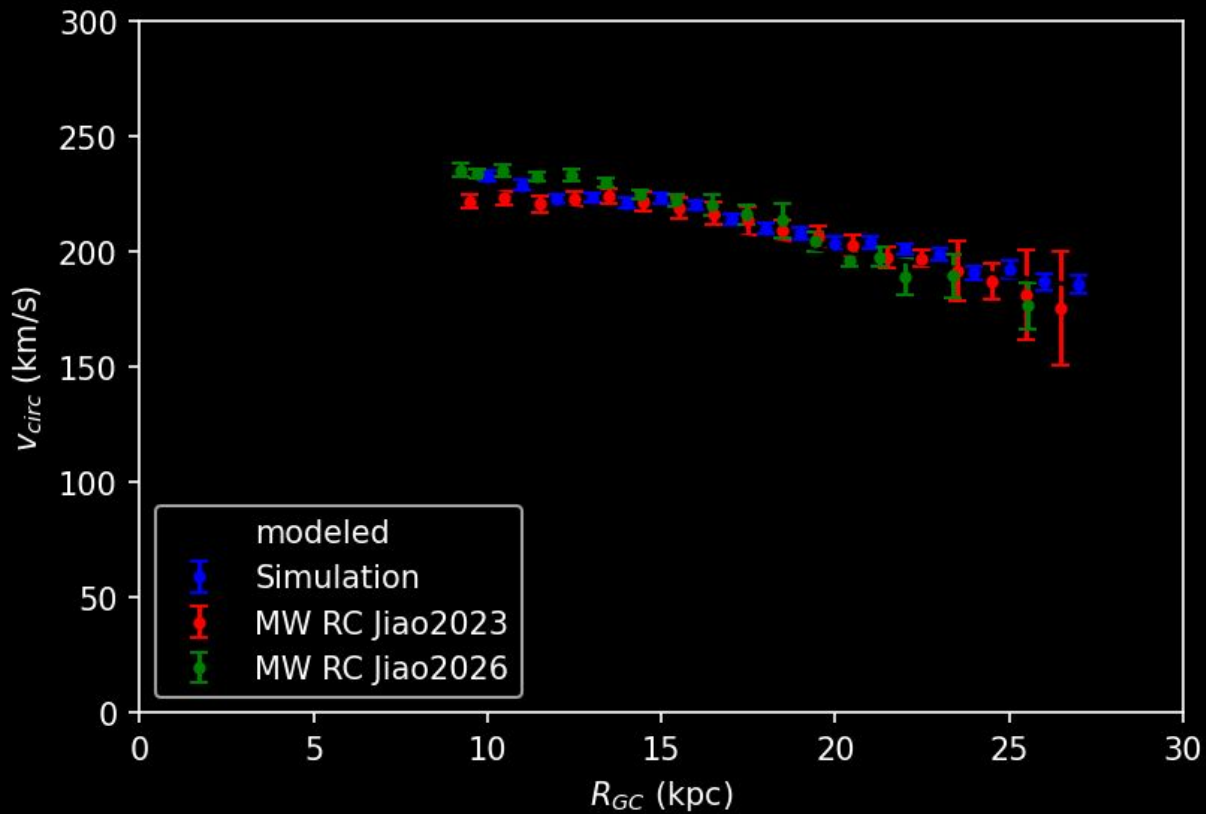


Surface Mass Density

surface stellar mass density from different baryon models

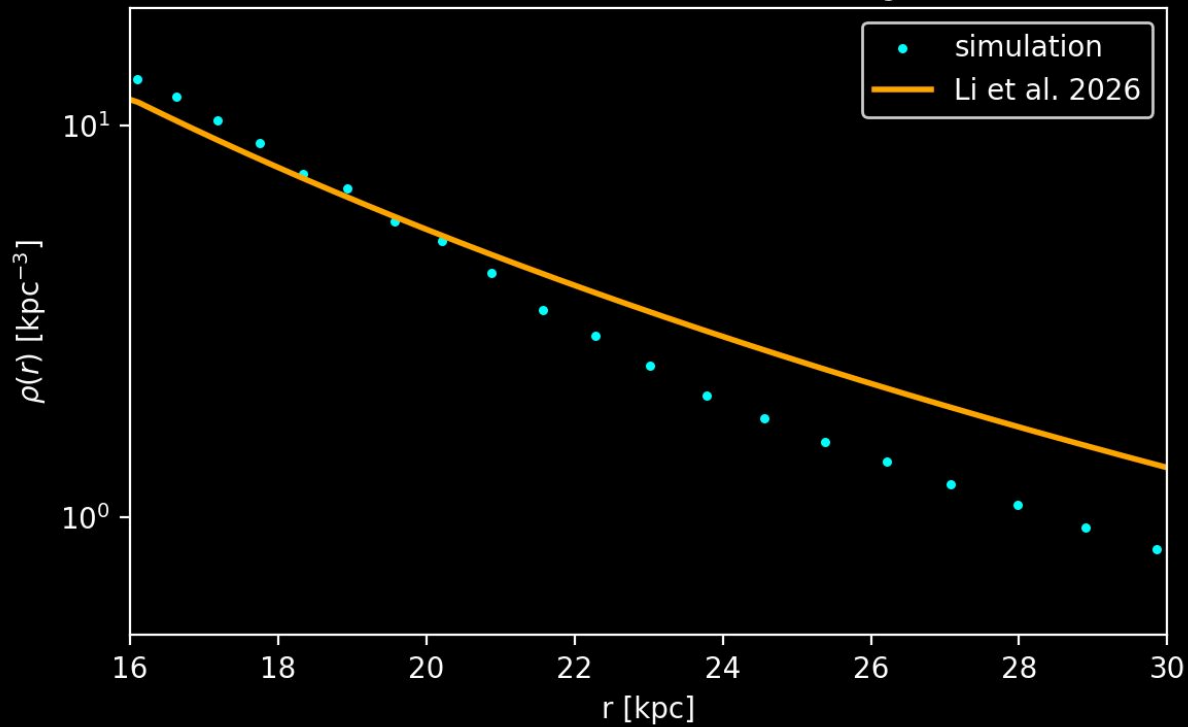


Rotation Curve

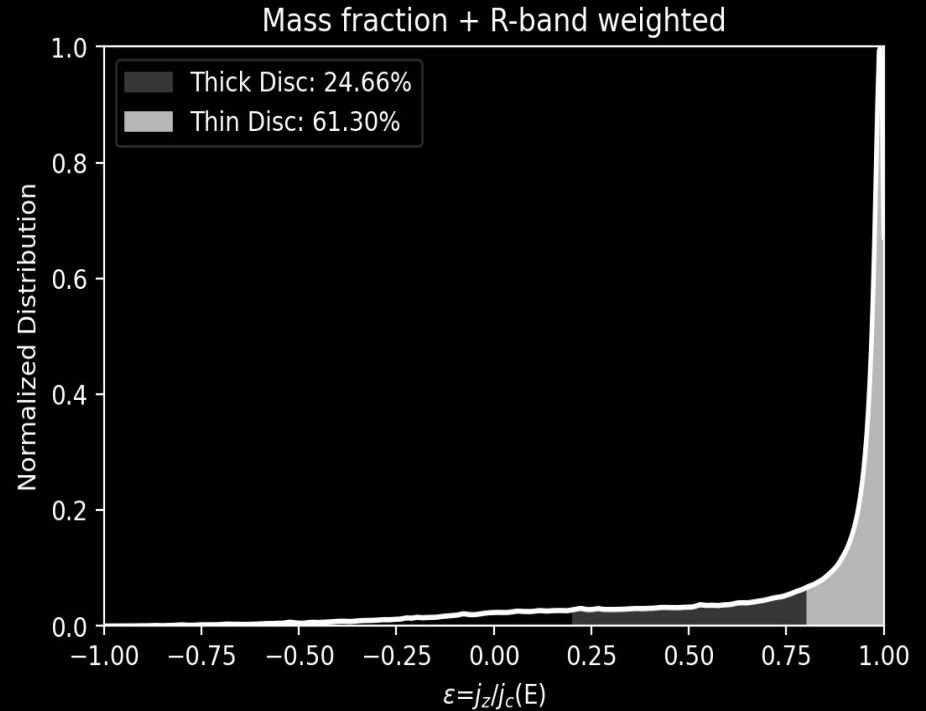
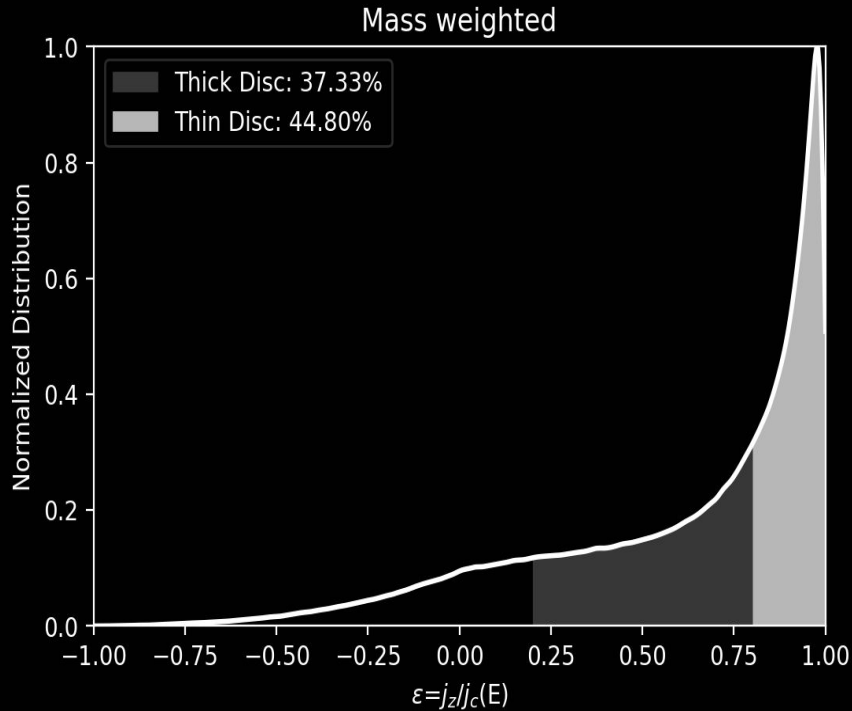


Halo Density Profile

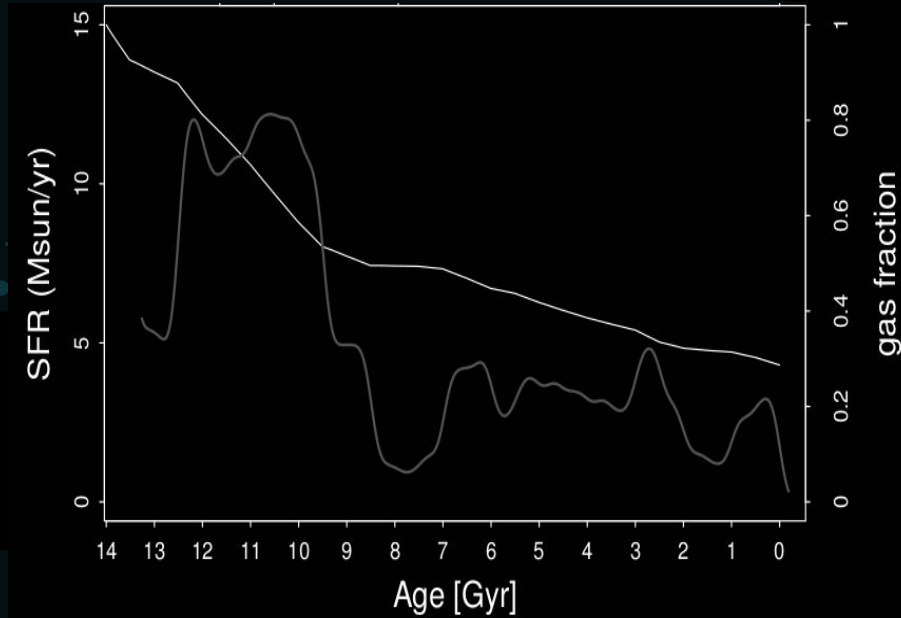
Stellar halo density ($|z| > 1$, $16 < R_{gc} < 30$)



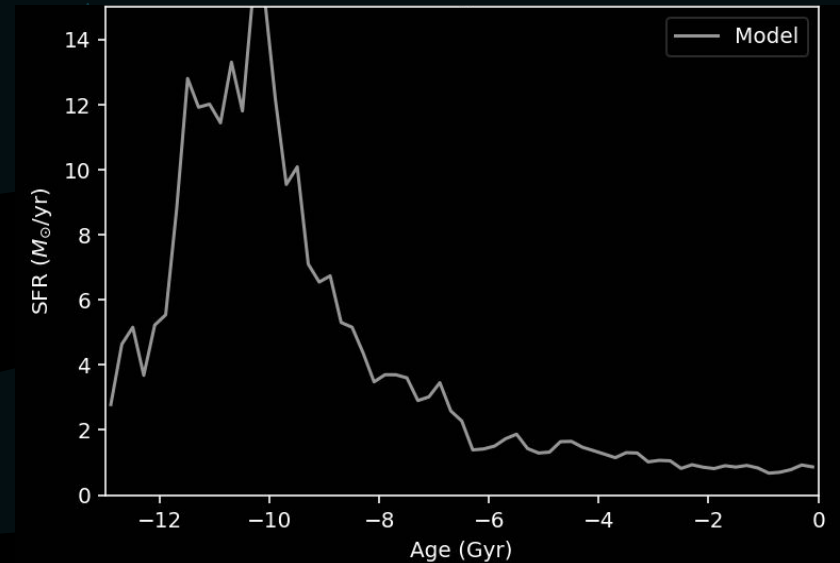
Thick and Thin Disc



Star Formation History

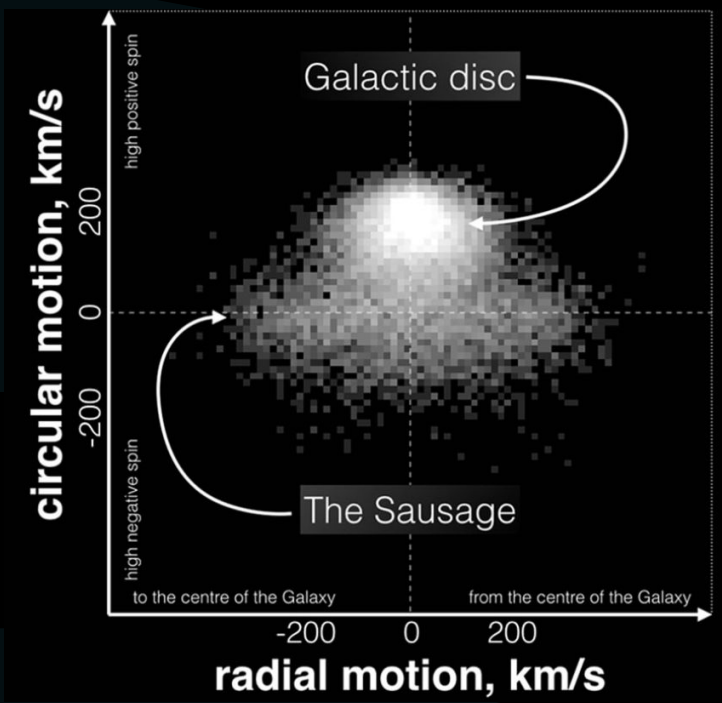


MW Star Formation: Haywood+ 2016

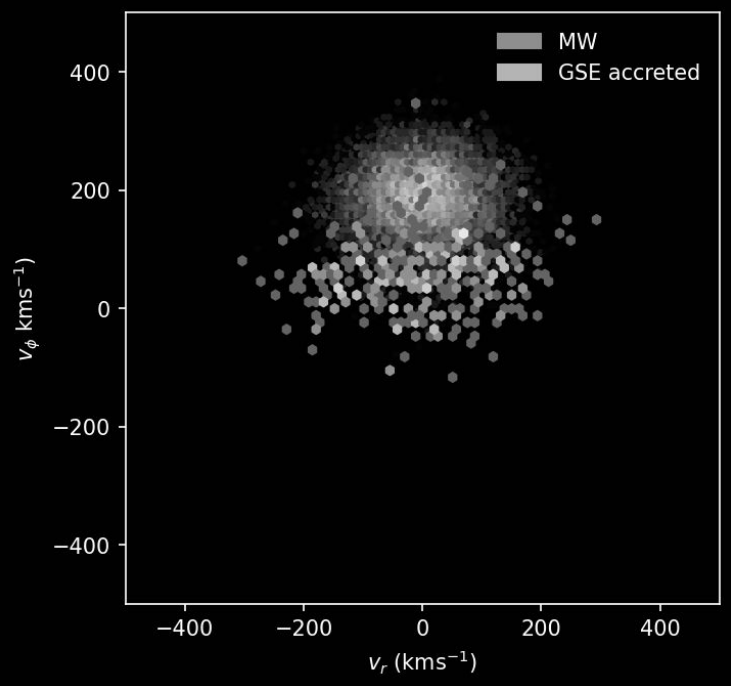


Our simulation

Merger Signature

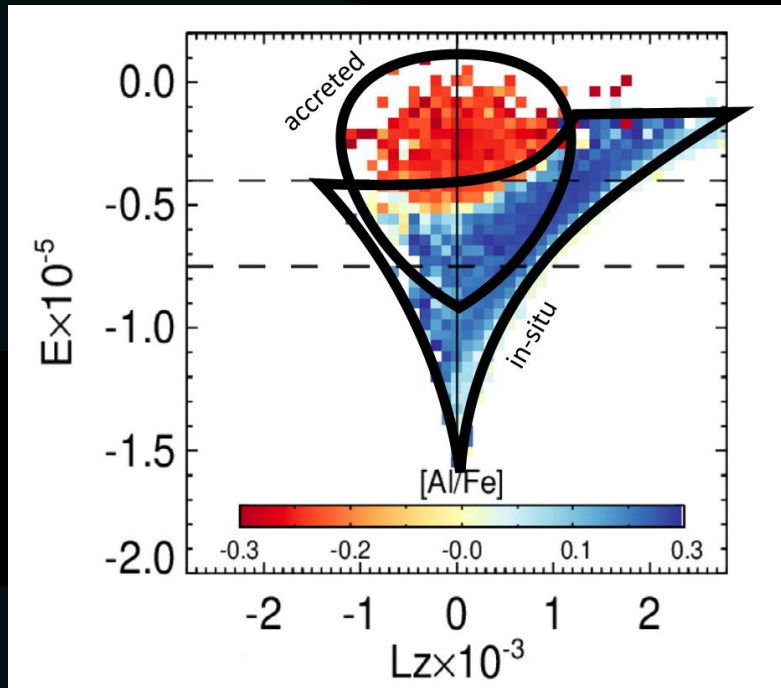


GSE, adapted from Belokurov + 2018

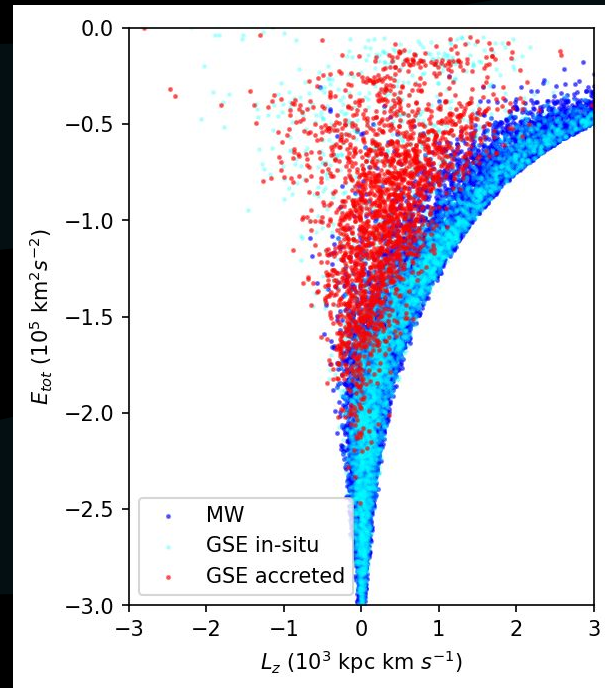


Stellar particles in our simulation

Merger Signature

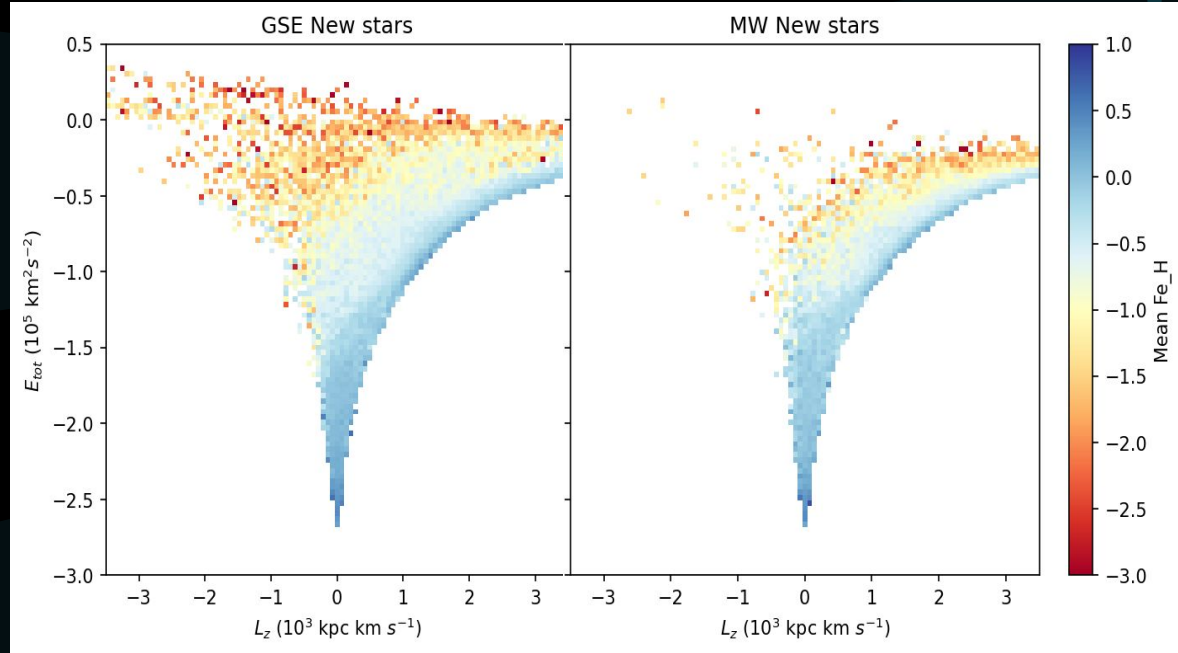
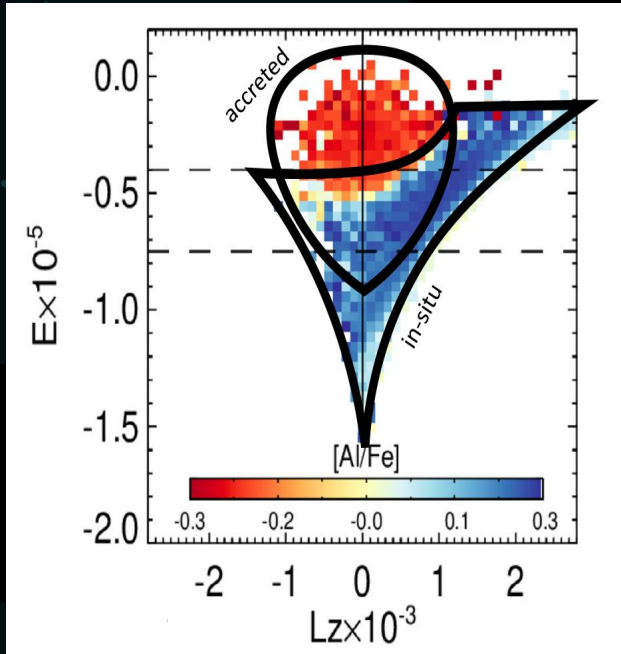


GSE, from Belokurov and Kravtsov (2022)



Our simulation

Merger Signature

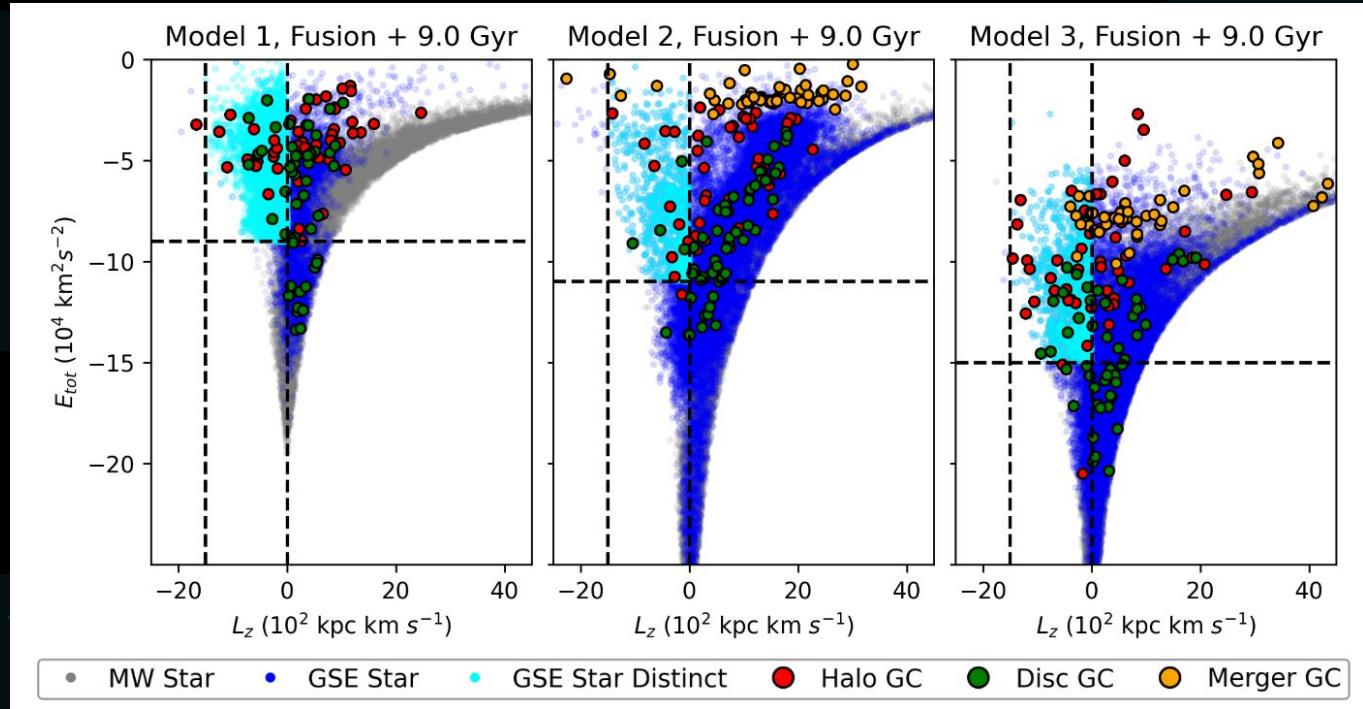


Belokurov and Kravtsov (2022)

Our simulation

Globular Clusters from GSE

We found GCs originally in the GSE halo or formed during merger keeps high energy and can be identified in the E-Lz plot



GCs in MW-GSE merger; from Akib et al. 2026



Conclusion

- We made a hydrodynamical simulation of the MW-GSE merger that reproduces the merger features
- Our simulations also reproduce most of the observed properties of the Milky Way
- **Ongoing tasks:**
 - Fine tuning and finding the best (or a few good) model(s)
 - Fe/H for thin vs thick disk and GSE identification
 - Impact of GSE merger on Warp and Flare



THANKS!

Do you have any questions?

CREDITS:

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