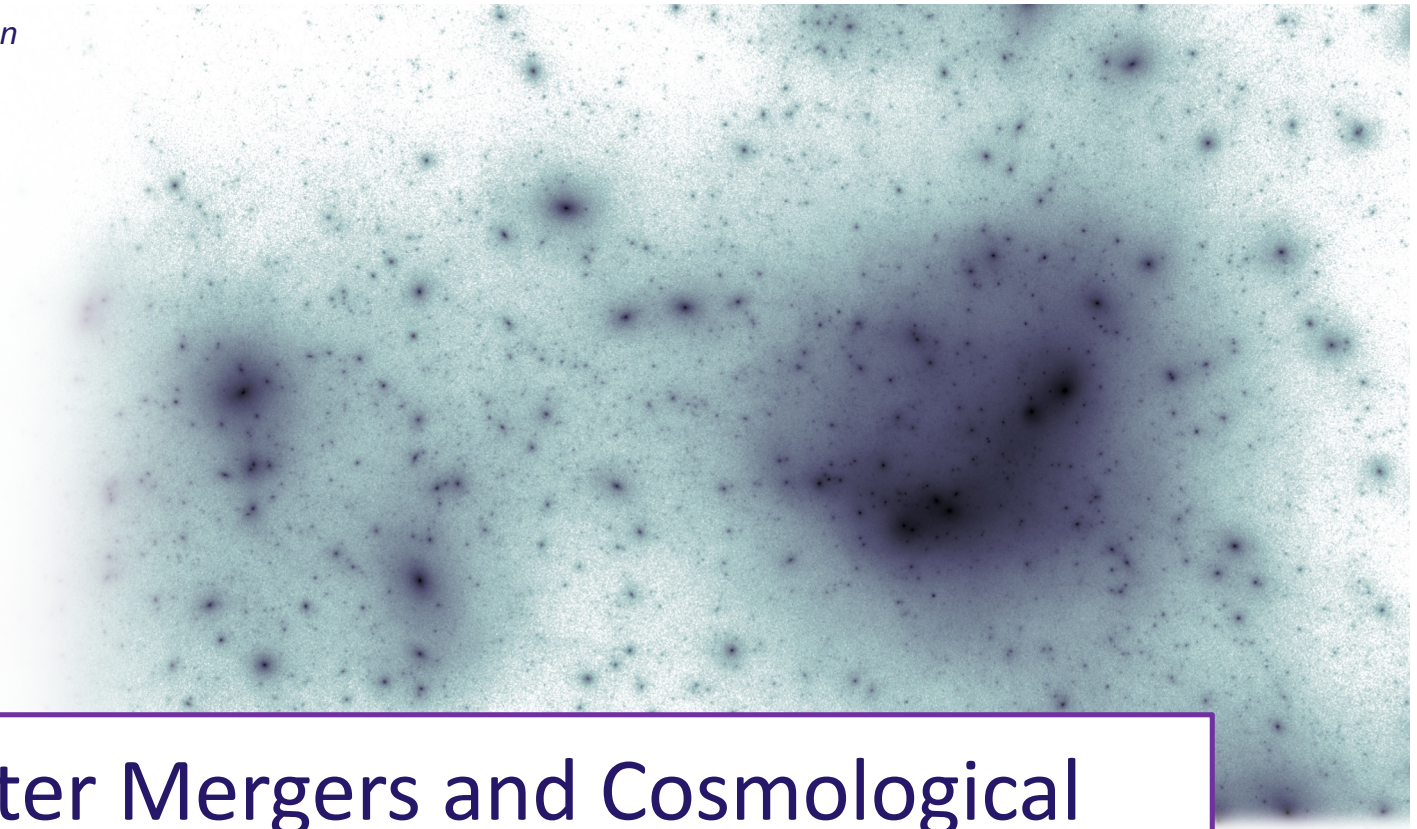
2024.10.31 KIAS Cosmology and Structure Formation



Galaxy Cluster Mergers and Cosmological Shockwaves in the TNG-Cluster Simulation

Wonki Lee

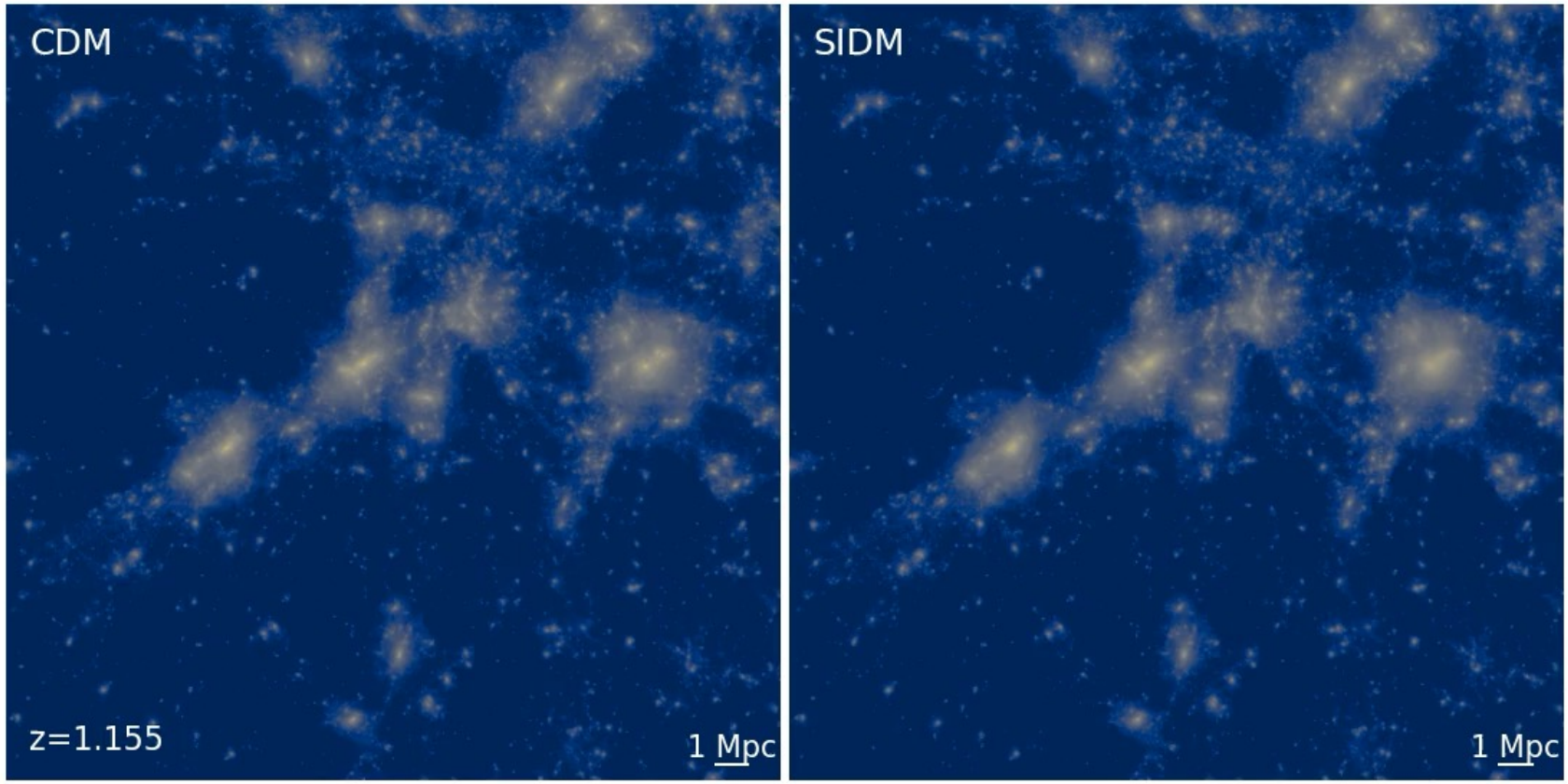
Yonsei university

With Annalisa Pillepich, John ZuHone, Dylan Nelson, M. James Jee, Daisuke Nagai, Kyle Finner

YOUNG
Yonsei Observable UNiverse Group

Galaxy Clusters in Structure Formation

Underlying physics modify the structure formation & cluster merger history



Cosmological shockwaves

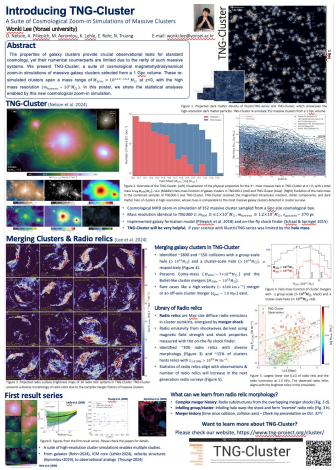


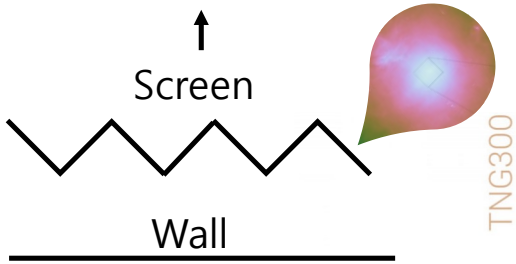
*What can we learn about **the merger history** using radio relics?*

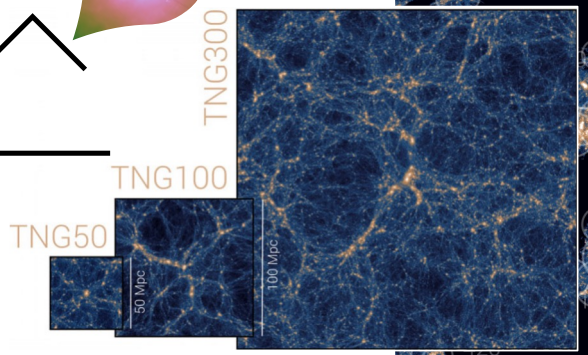
Introducing

TNG-Cluster

- Cosmological MHD zoom-in simulations of 352 clusters sampled from 1 Gpc box.
- Resolution: $m_{\rm baryon} \sim 10^7 M_\odot$ TNG galaxy formation models
- $\boldsymbol{N\left(M_{200c} > 10^{15} M_\odot\right) = 92}$

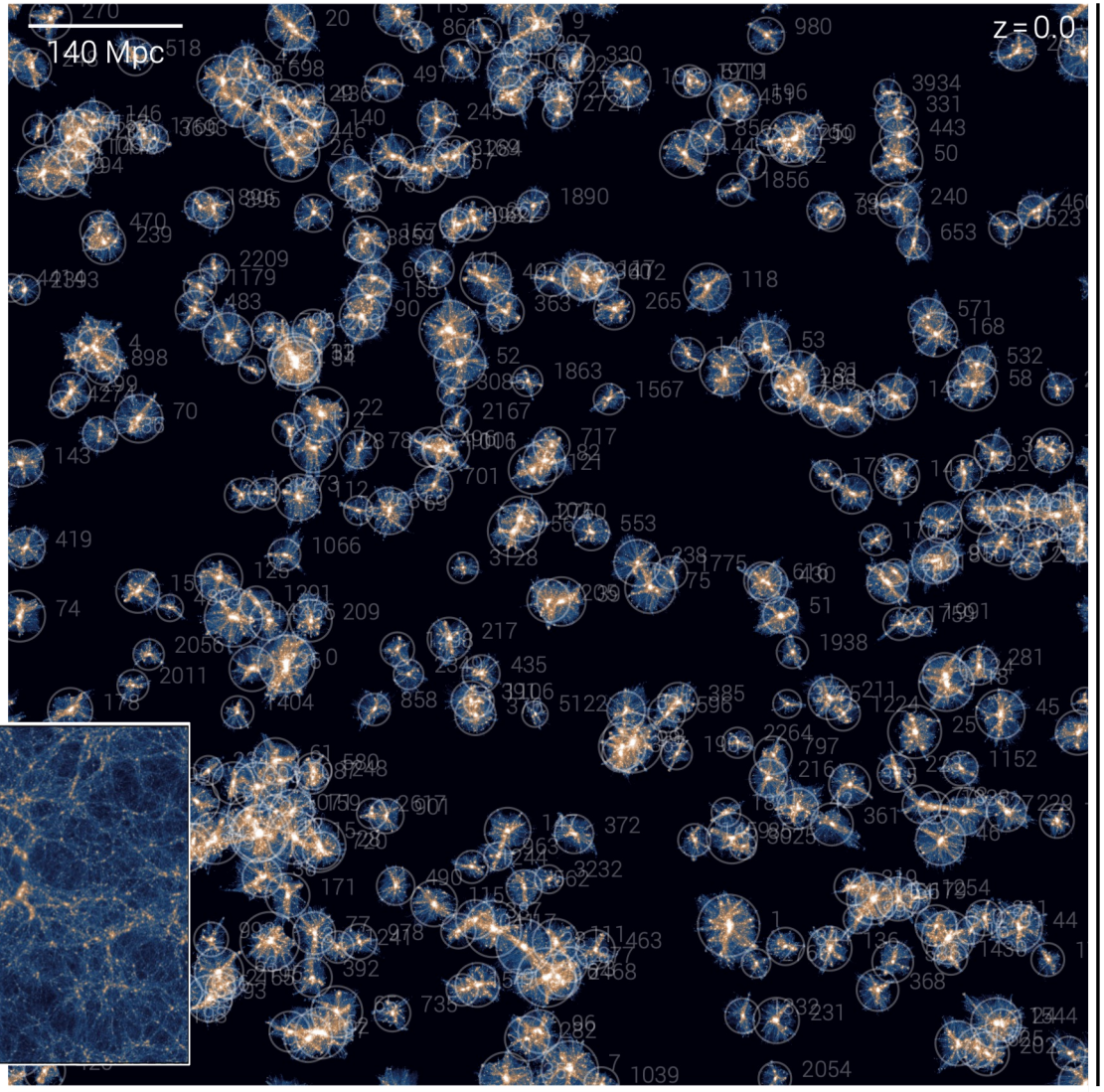






TNG-Cluster

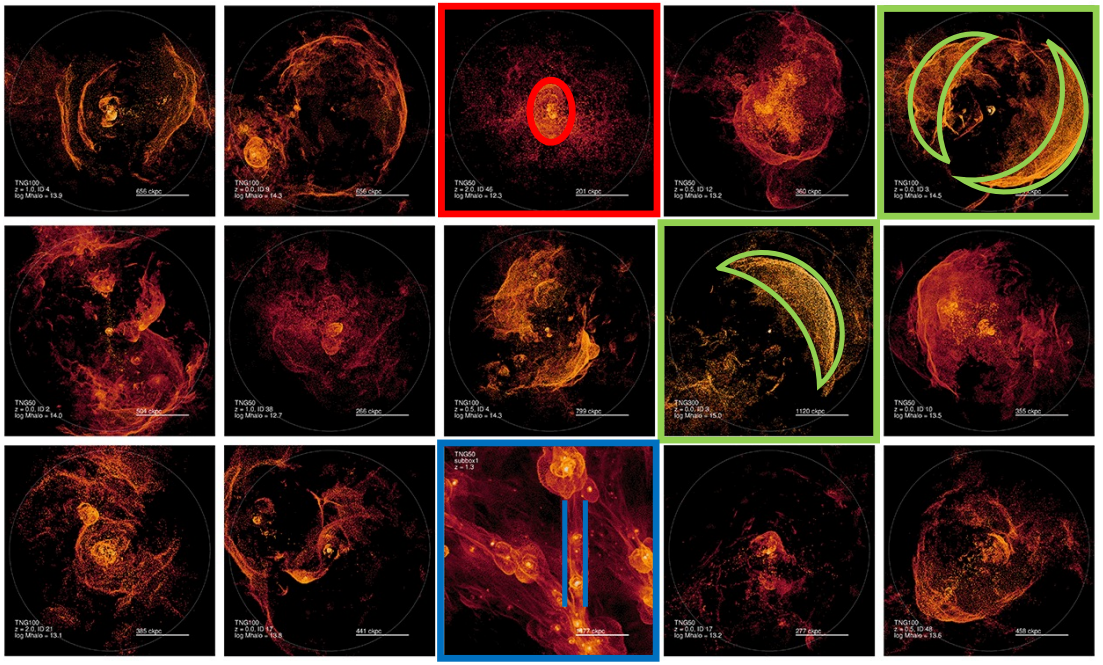
Nelson et al. (2024)

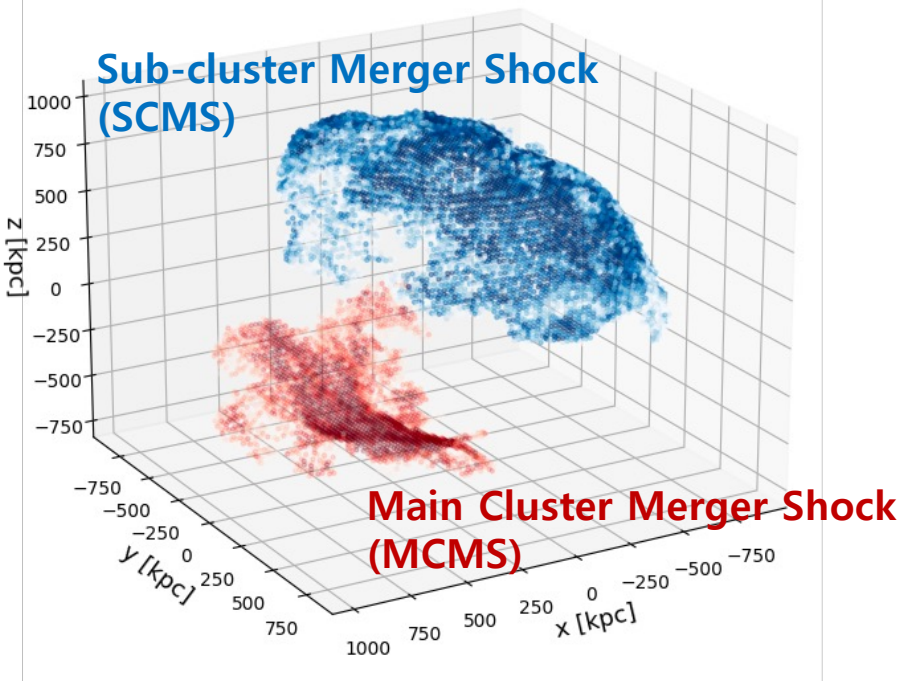


Extracting radio relics from cosmological simulation

- Cosmological shockwaves formed by multiple sources (**merger**, **accretion**, **AGN feedback**…)
- Grouping shock dissipated energy based on their spatial connectivity

→ Largest shockwaves + Most energetic shockwaves (to exclude AGN and accretion shocks)

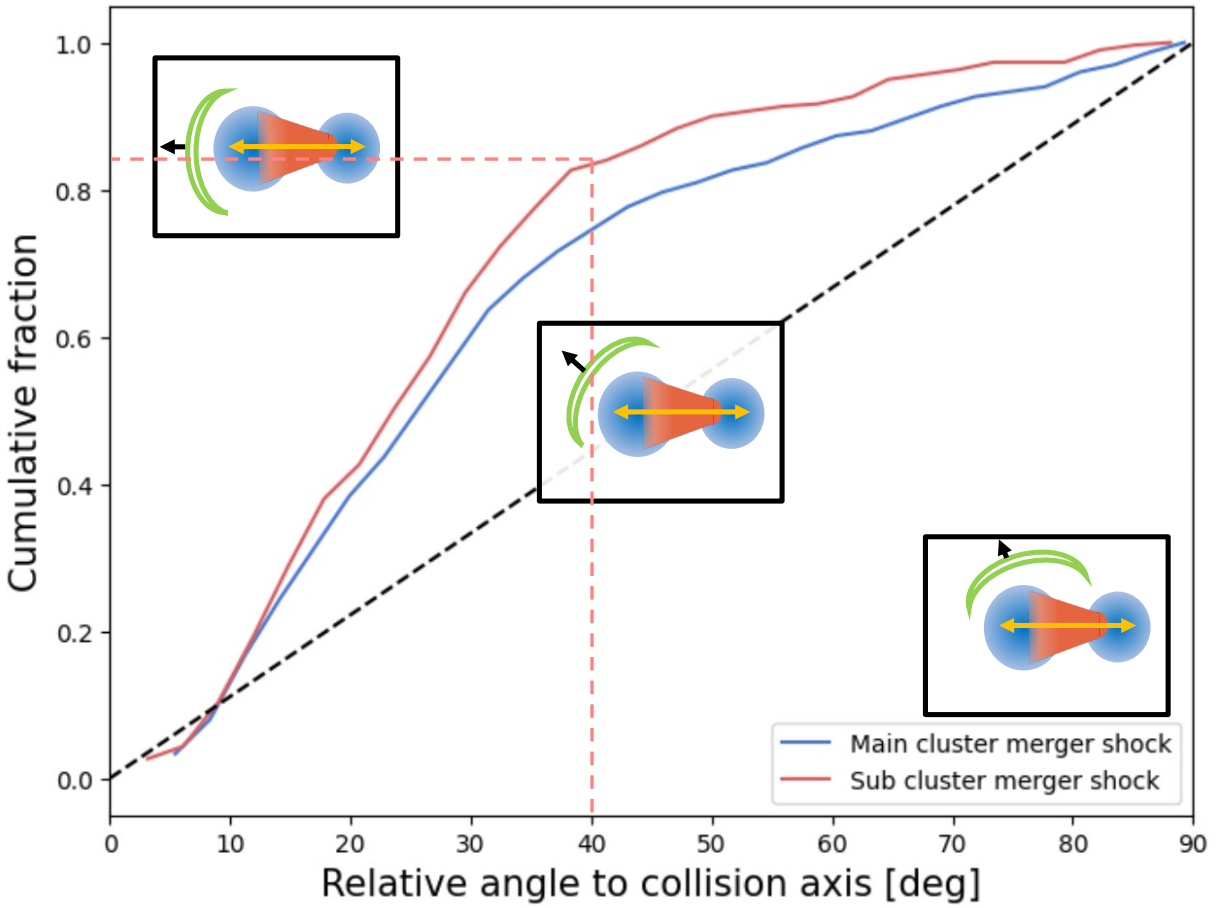




Can radio relics inform collision axis?

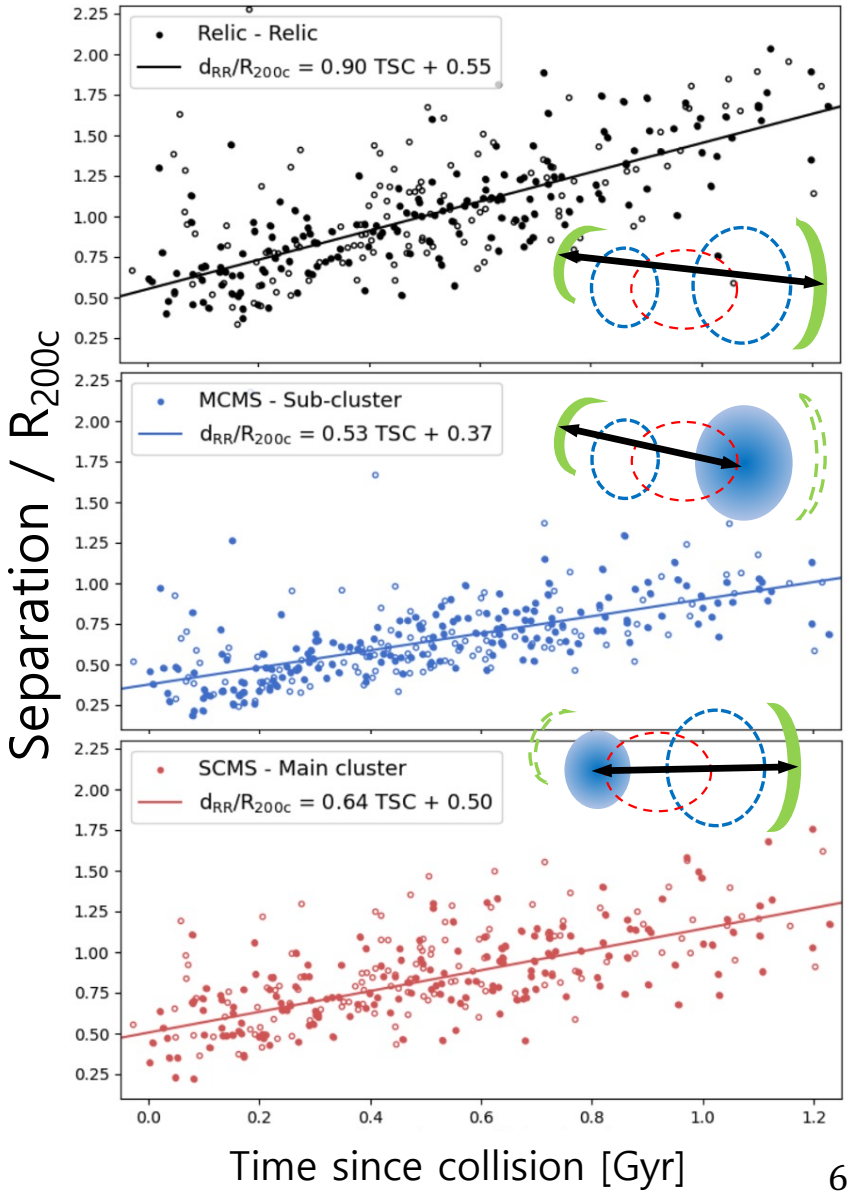
- **Yes** – Normal vector of the radio relics aligns with the collision axis, which can inform the collision axis.

- **Collision axis** : Direction of cluster relative motion at the pericenter
  Normal vector: Minor axis in the PCA of the 3D radio relic distribution

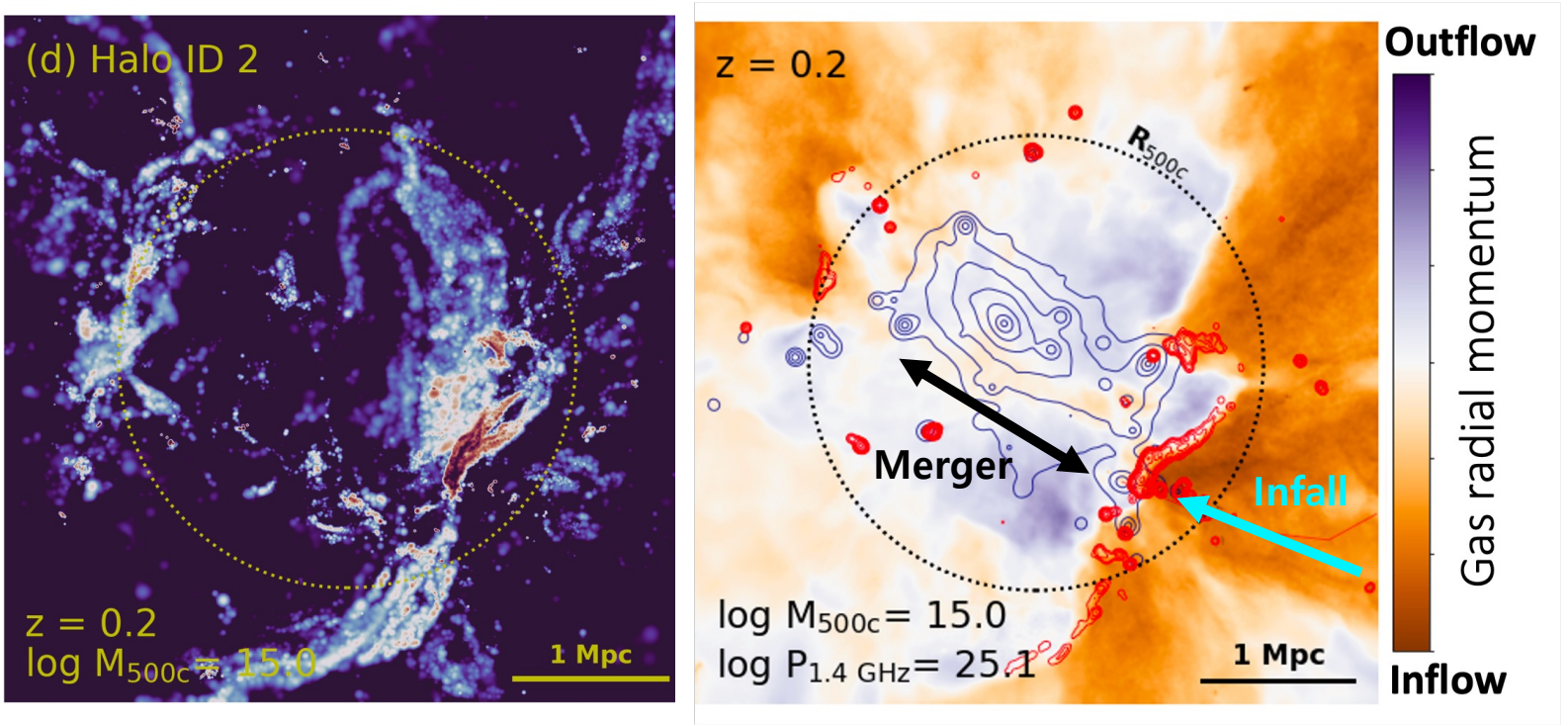


Can we constrain time with relics?

- **Yes** – Relic-to-relic separation & relic-to-halo separation increase linearly with time
- Separate Isolated (•) & Multiple mergers (◦) based on cluster merger events within ±2 Gyrs
- *What caused the large variation?*



Radio relic formation & complex merger history

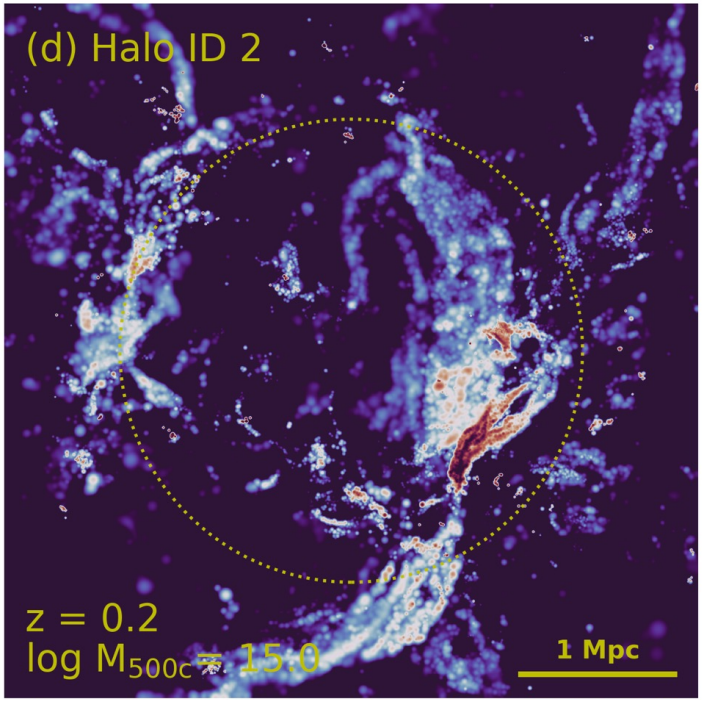


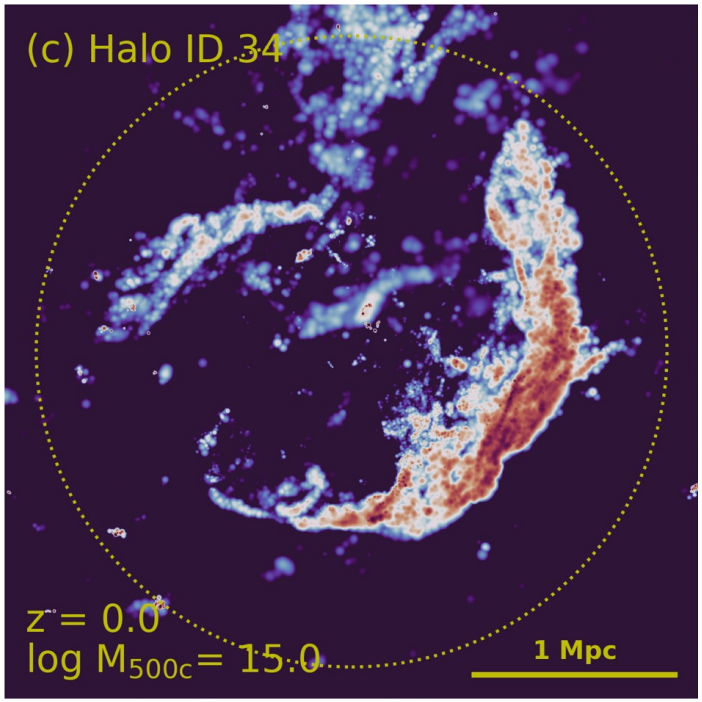
Radio relic formation & complex merger history

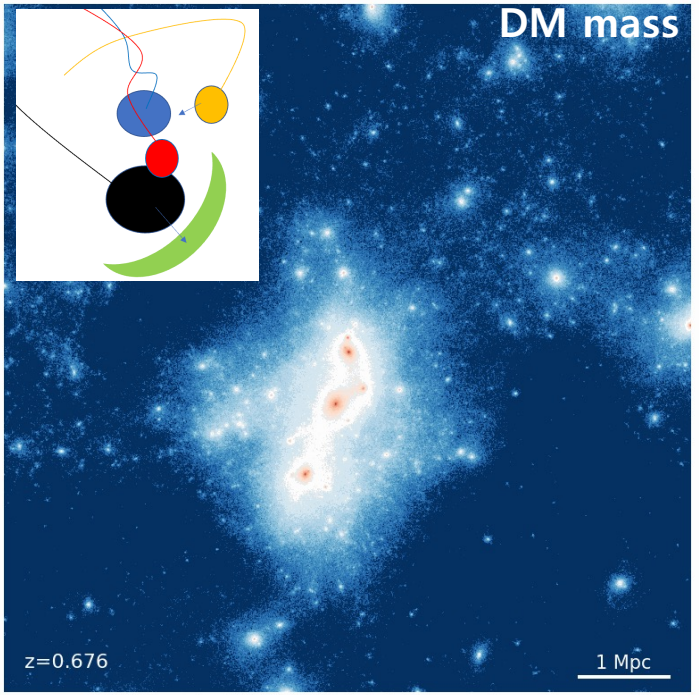
- Complex merging history can amplify/modify radio relic properties.

  → Observed radio relics could be results of multiple cluster merger events

- *Can we use radio relics to interpret merger history?*







Example

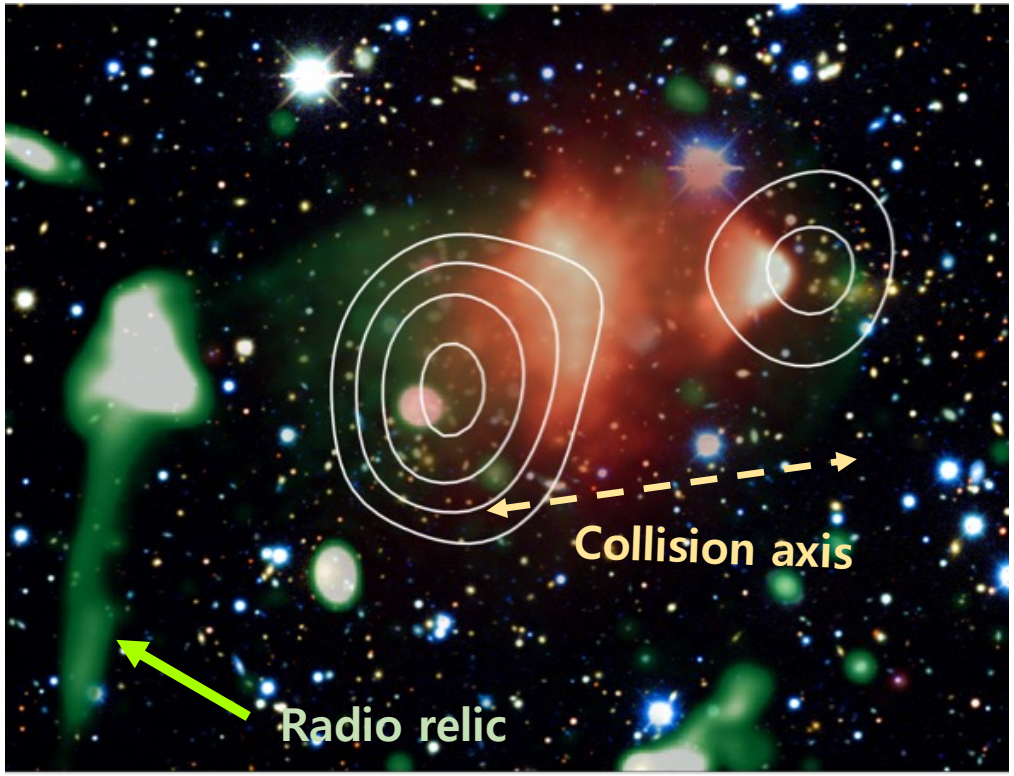
Radio relic to merger history



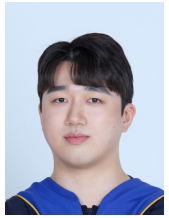
Cho et al. (to be submitted)



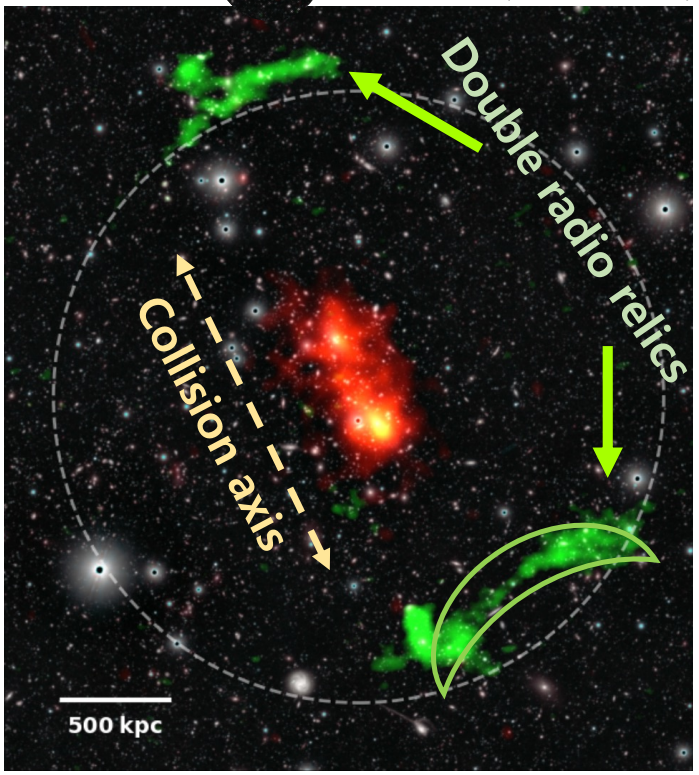
Boseong Cho



Ahn et al. (to be submitted)



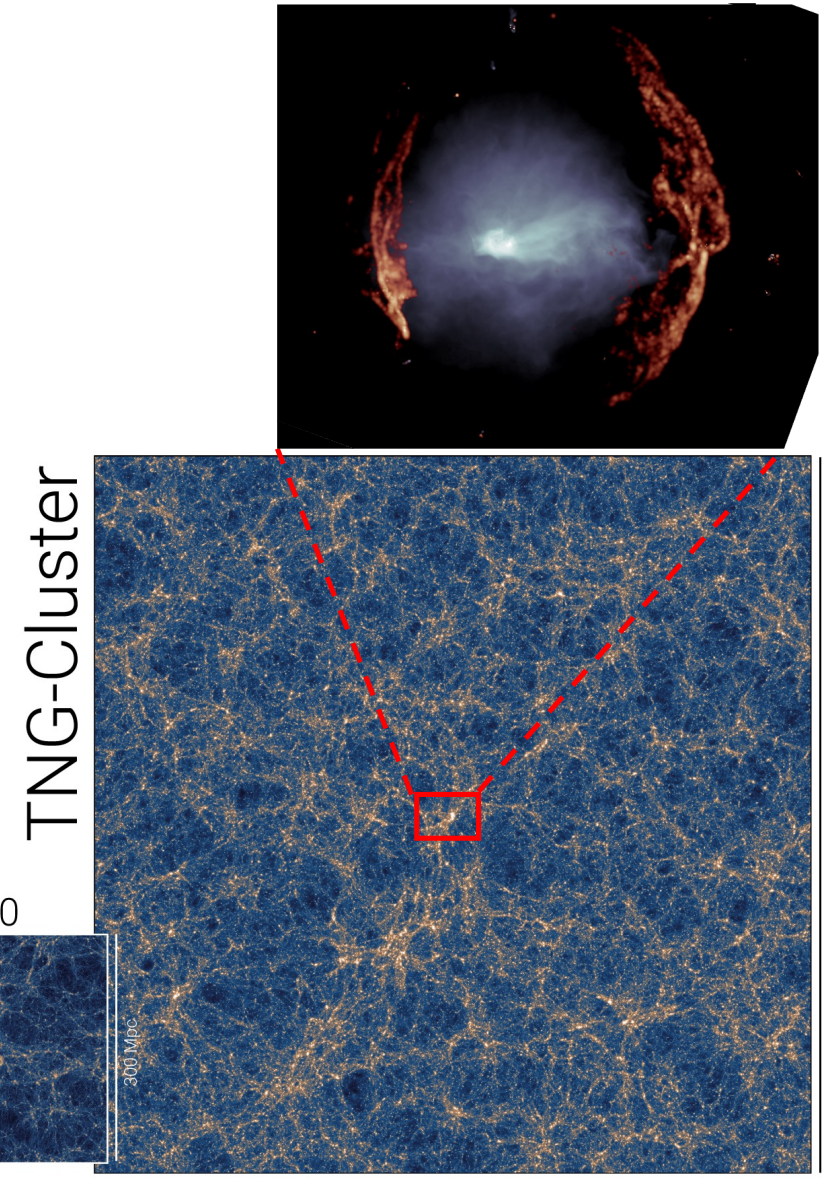
Eunmo Ahn



- Collision axis from the radio relic extension, larger time since collision with larger separation
- Diverse morphology: Single & inverted radio relic

Summary

- Cosmological MHD zoom-in simulation TNG-Cluster provides a large collection of massive cluster mergers.
- **Radio relics can constraint merger history**, including collision axis, and time since collision.
- However, caution is required in using radio relics due to the complex merger history.



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Advertisement

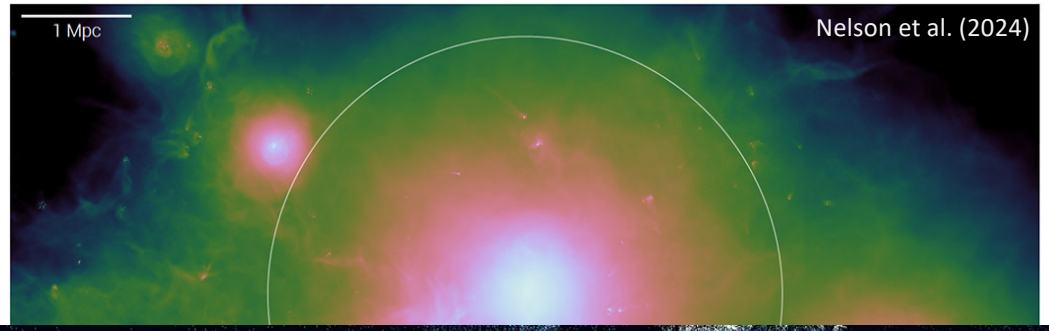
TNG-Cluster

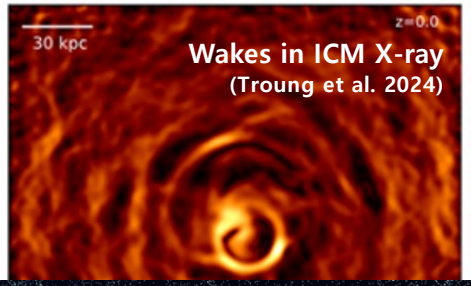
Scale

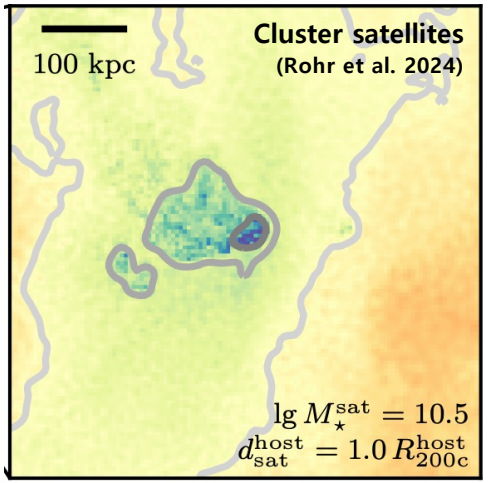
$N_{\rm cluster} = 352\ (\sim 680)$

$M_{\rm DM} \sim 6 \times 10^7 M_\odot$

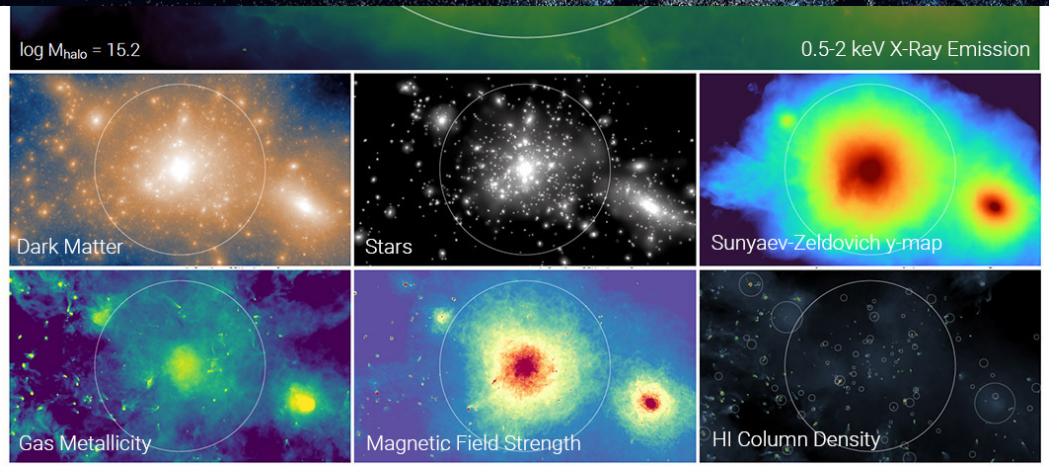
$M_{\rm baryon} \sim 10^7 M_\odot$

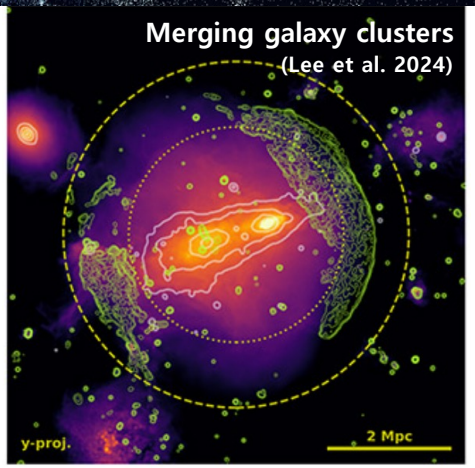


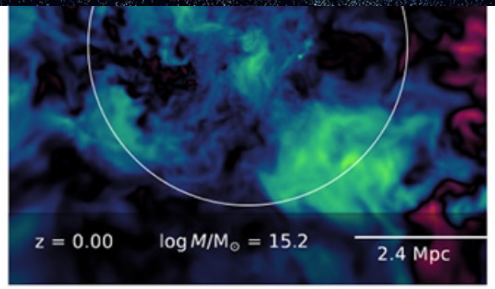




Thank you for your attention







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2024.10.31