SSG workshop 2024.01.31

Spatial Distribution of Intracluster Light vs. Dark Matter in Horizon Run 5

KIAS KOREA INSTITUTE FOR ADVANCED STUDY

Jaewon Yoo

Intracluster Light

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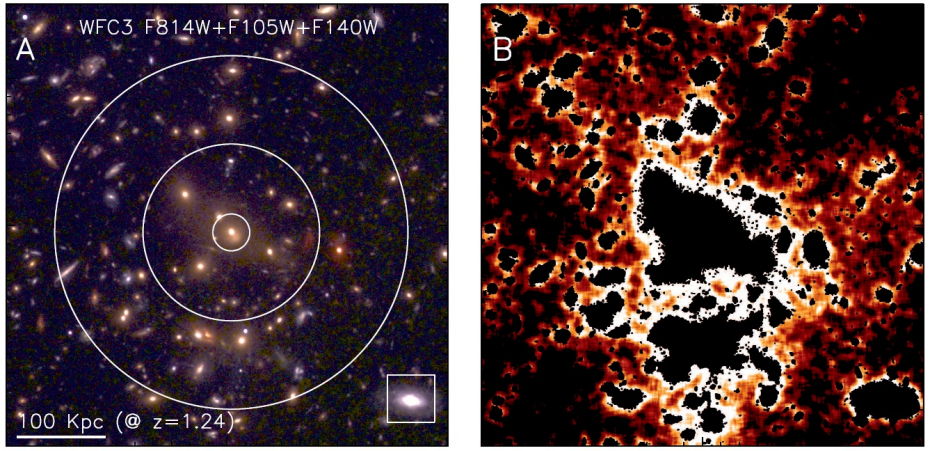
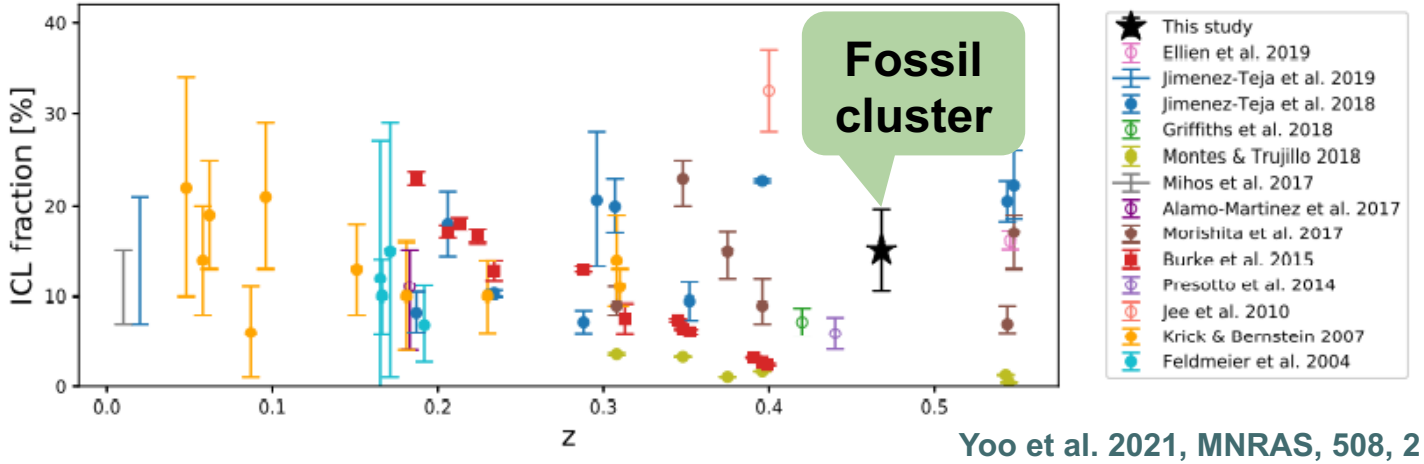


MOO J1014+0038 Ko & Jee 2018



Yoo et al. 2021, MNRAS, 508, 2

Definition of Intracluster Light (ICL)

The light from stars which are bound to the cluster but not to the galaxies within them.

- ICL increases through **interactions between galaxies** in galaxy cluster.

Meaning of ICL research

1. **Collisionless & follow grav. pot → <u>Luminous tracer for Dark Matter</u>**
2. **<u>Probing the evolutionary stage</u> of the galaxy clusters**

Comparison of Spatial Distribution

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- ***Can you tell how similar those maps are, in a number?***

WOC method

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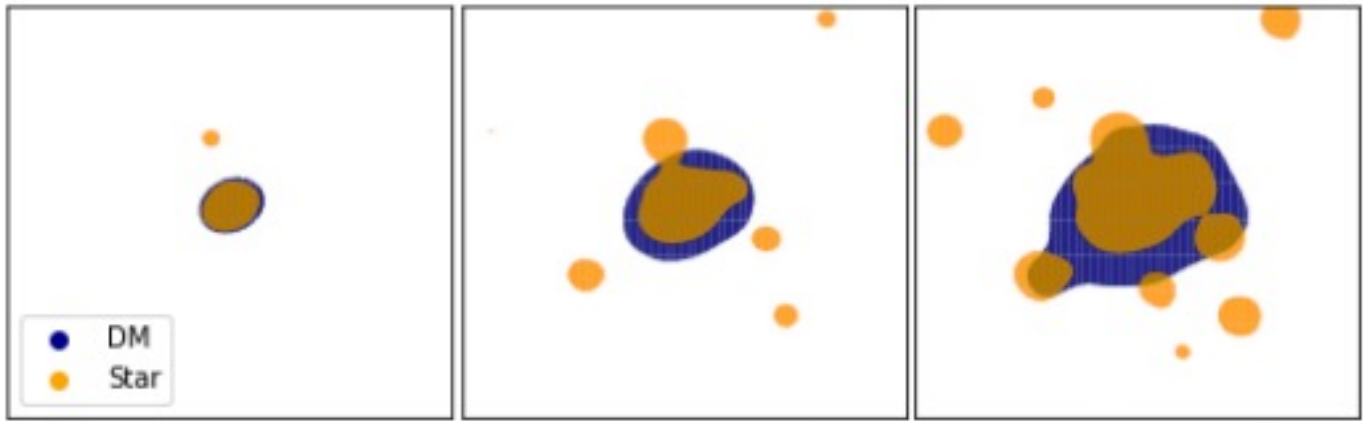
Give Weight to the overlapping area

Yoo et al. 2022, ApJS, 261, 28

1st Level | 2nd Level | 3rd Level



Weighted Overlap Coefficient

$$\mathrm{WOC}(A,B) = \frac{\sum_{i=1}^{n} f_i\,(w_i + w_{\rho_A,i} + w_{\rho_B,i})}{\sum_{i=1}^{n} (w_i + w_{\rho_A,i} + w_{\rho_B,i})},$$

$$f_i = \mathrm{area}(A_i \bigcap B_i)/\mathrm{area}(A_i)$$

➢ **Give number between 0 and 1**

➢ ***If you want to quantify the similarity of spatial distributions..***

✓ **The WOC method code is available for public use!** https://github.com/csabiu/WOC

```
pip install pywoc
```

Horizon Run 5

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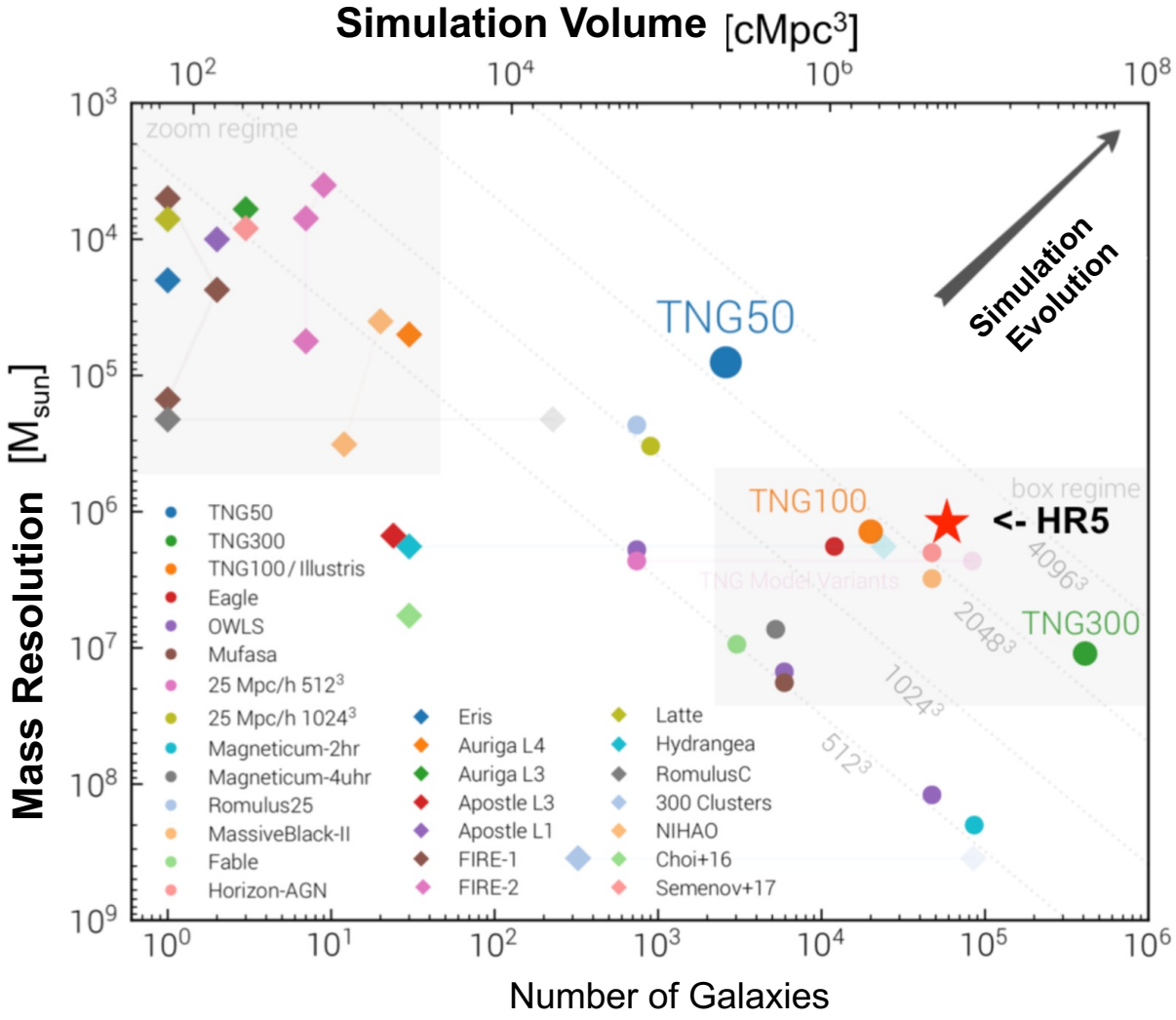
- **The top-biggest cosmological gravity-hydrodynamic simulation**
  - 8 times bigger than TNG100, EAGLE, Horizon-AGN
  - L_{box}= 1 h^{-1} Gpc
  - Zoom-in simulation
  - 1 ckpc resolution
- **Galaxy catalogs from**

$$z = 15 \text{ to } z = 0.625$$



Lee et al. 2021, ApJ, 908, 11

Galaxy Cluster Components

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$> 5\times 10^{13} M_{\odot}$ @ z=0.625
174 clusters

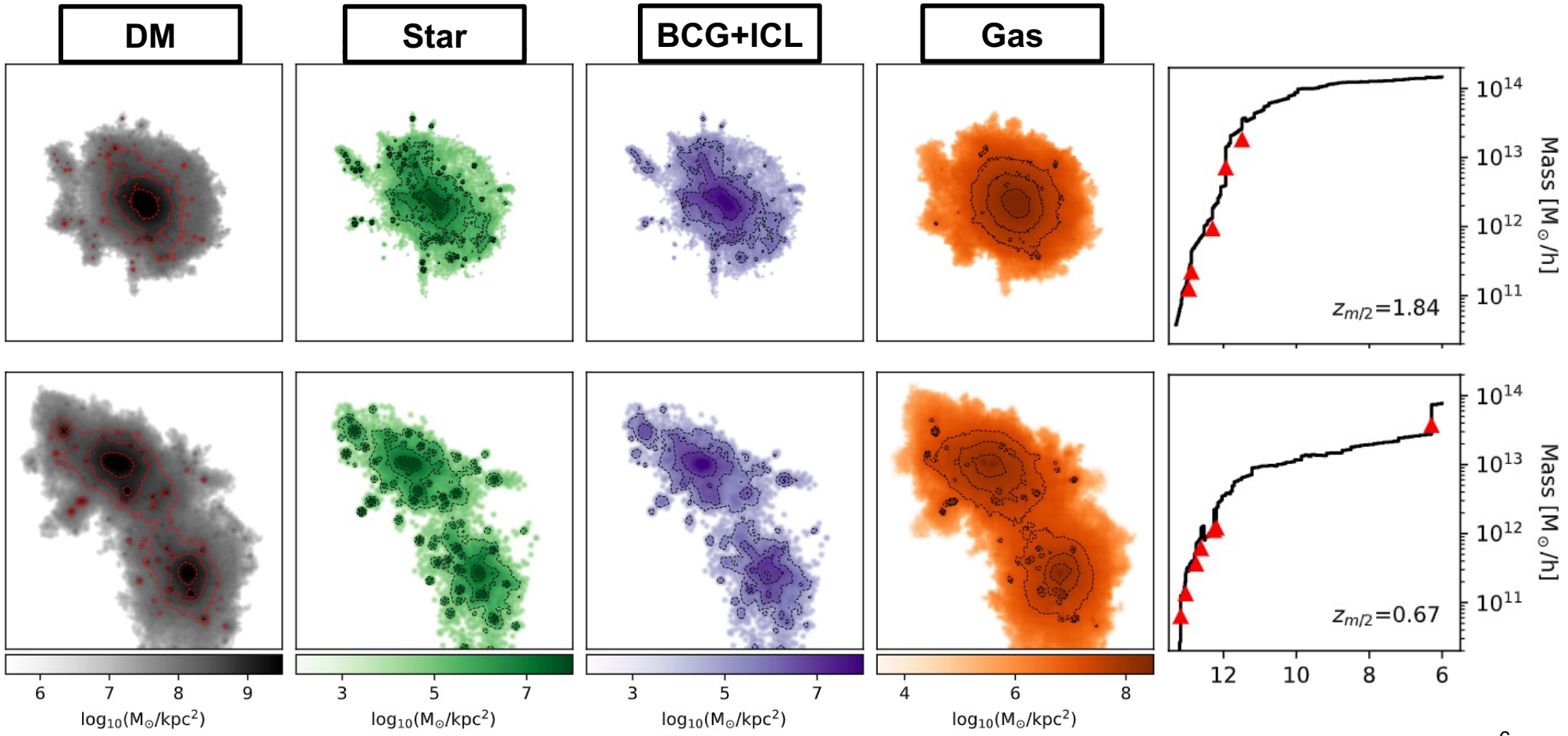
BCG + ICL + Satellite galaxy

Relaxed Galaxy Cluster

Image: 2 x 2 R_{vir}

Unrelaxed Galaxy Cluster

Image: 2 x 2 R_{vir}



WOC Result

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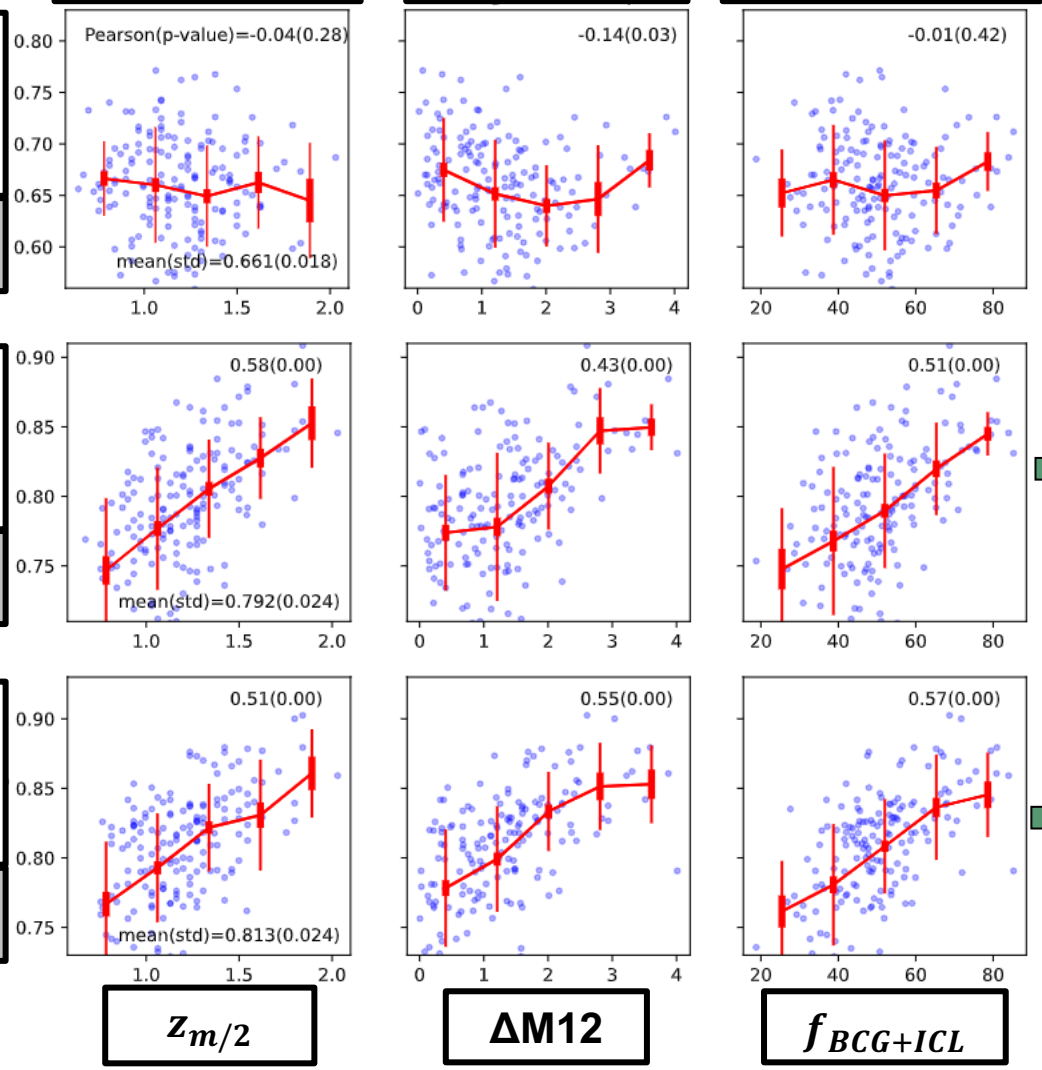
$> 5\times 10^{13} M_{\odot}$ @ z=0.625
174 clusters

	Half-mass Epoch	Magnitude Gap	BCG+ICL Fraction
DM vs. Star	0.661		
DM vs. BCG+ICL	0.792		
DM vs. Gas	0.813		



BCG+ICL and Gas trace DM better than Stars!

More relaxed galaxy cluster has higher similarity bw. DM and BCG+ICL / Gas!

WOC variation

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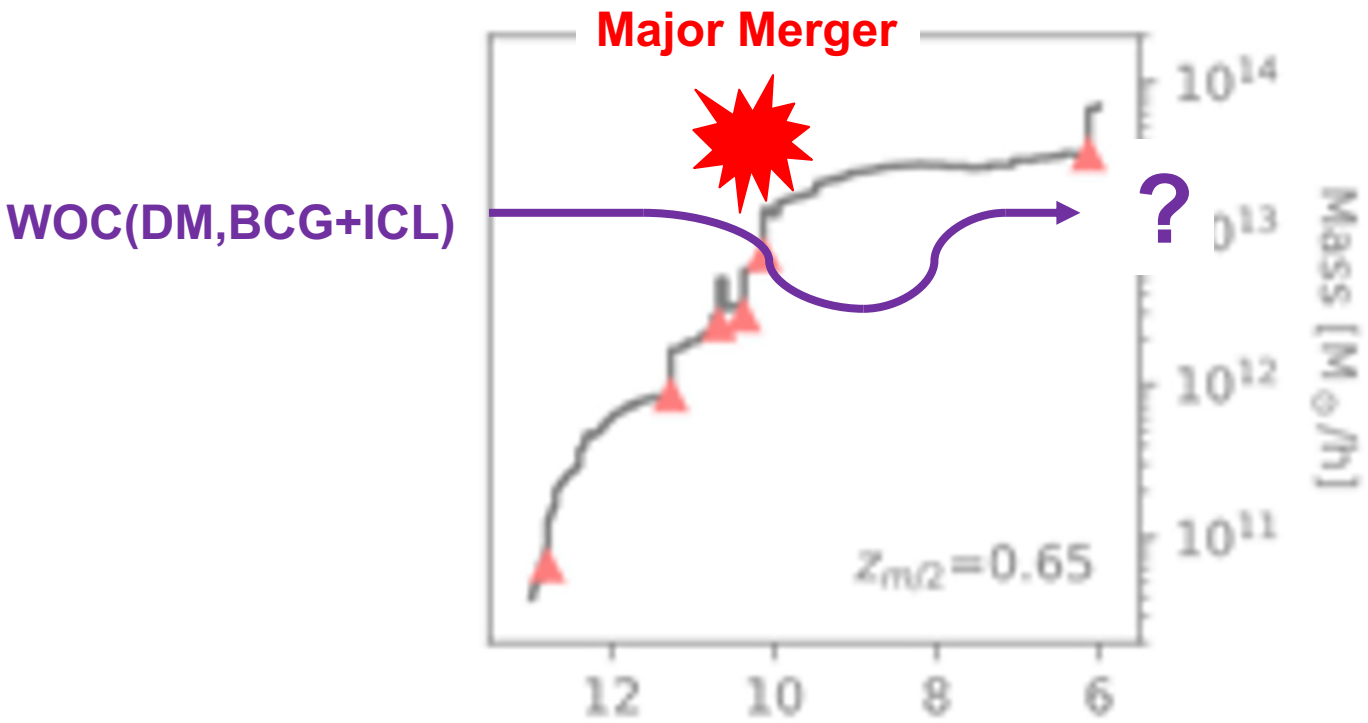
- WOC evolution (before/ after major merging)



WOC veriation

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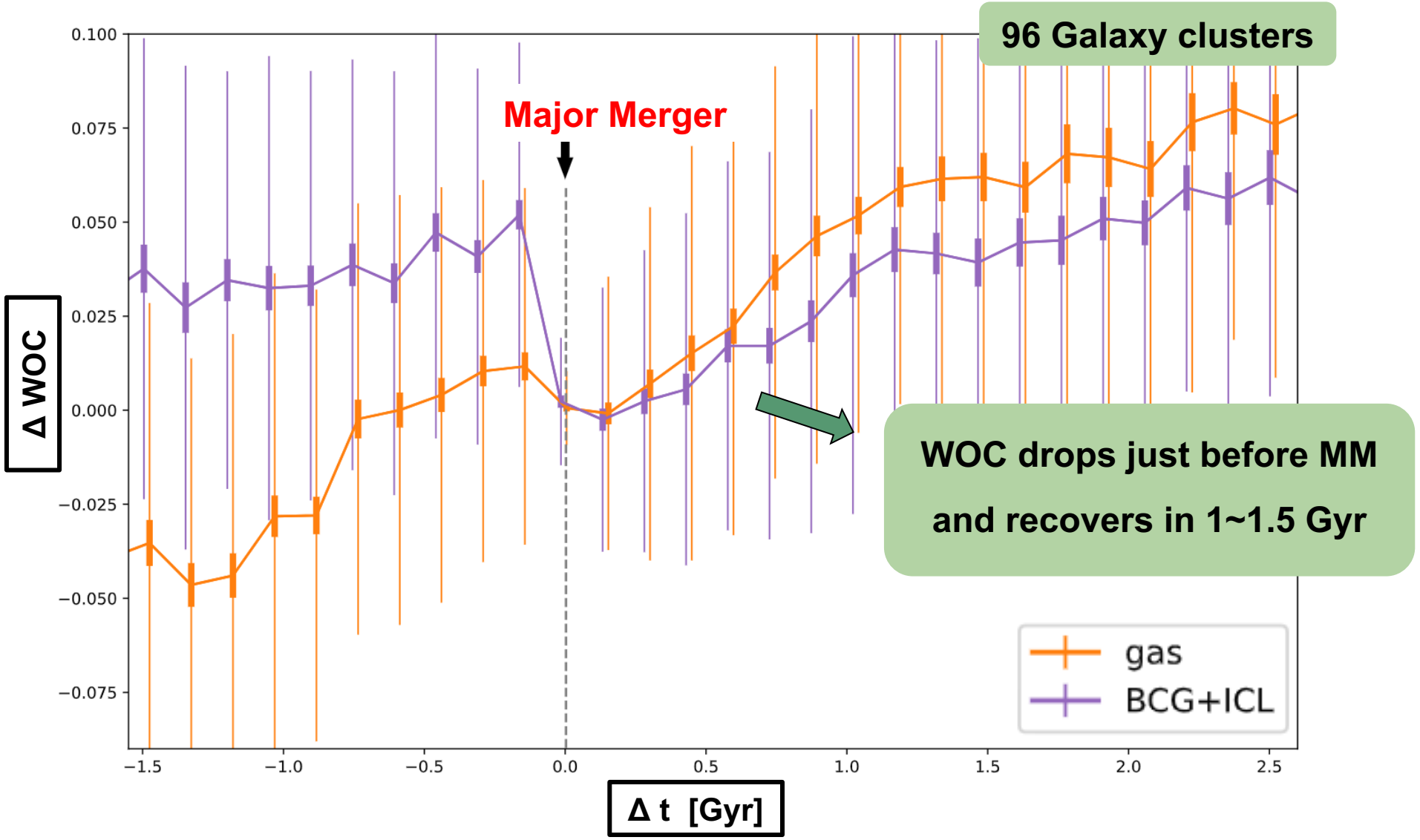

WOC Evolution

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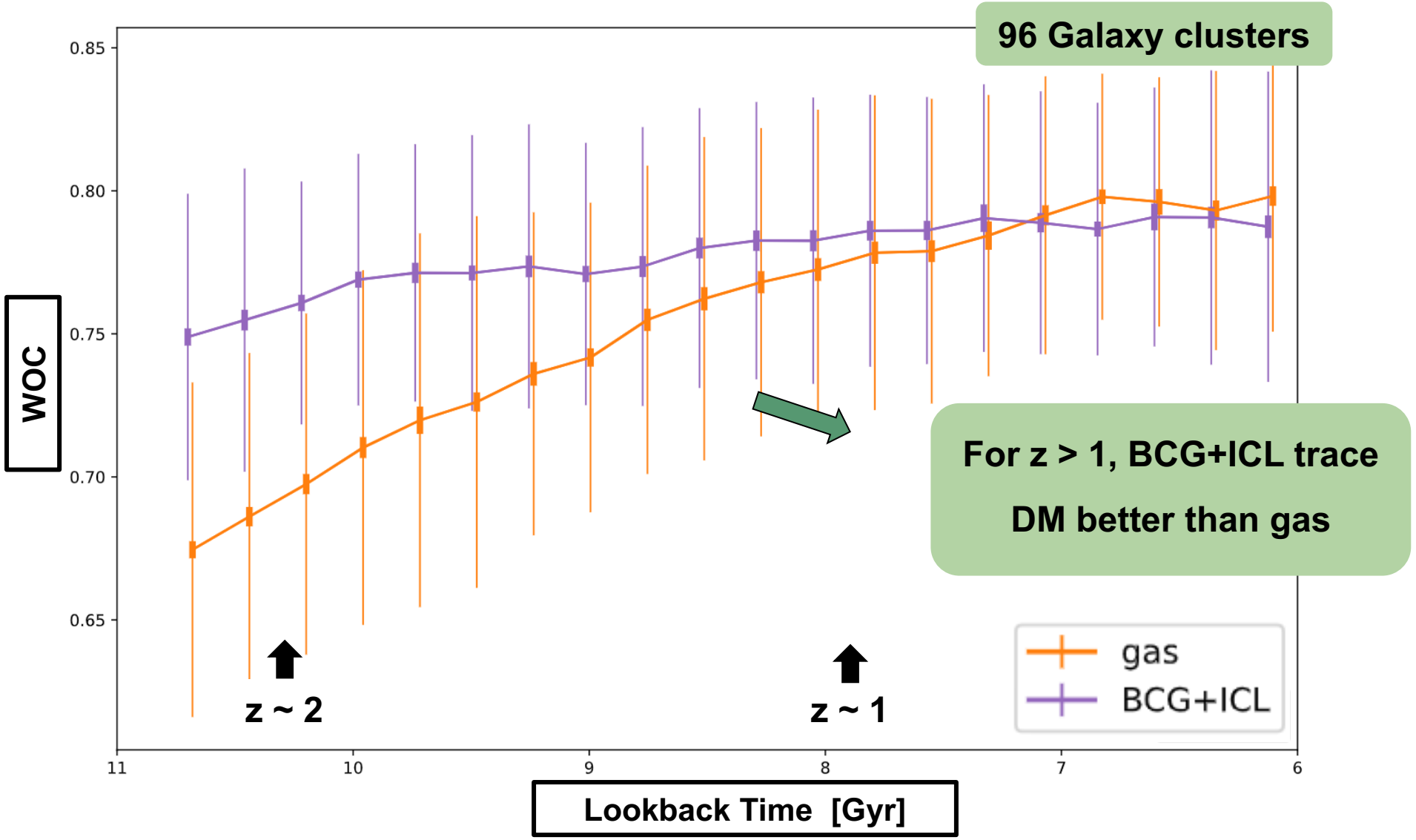
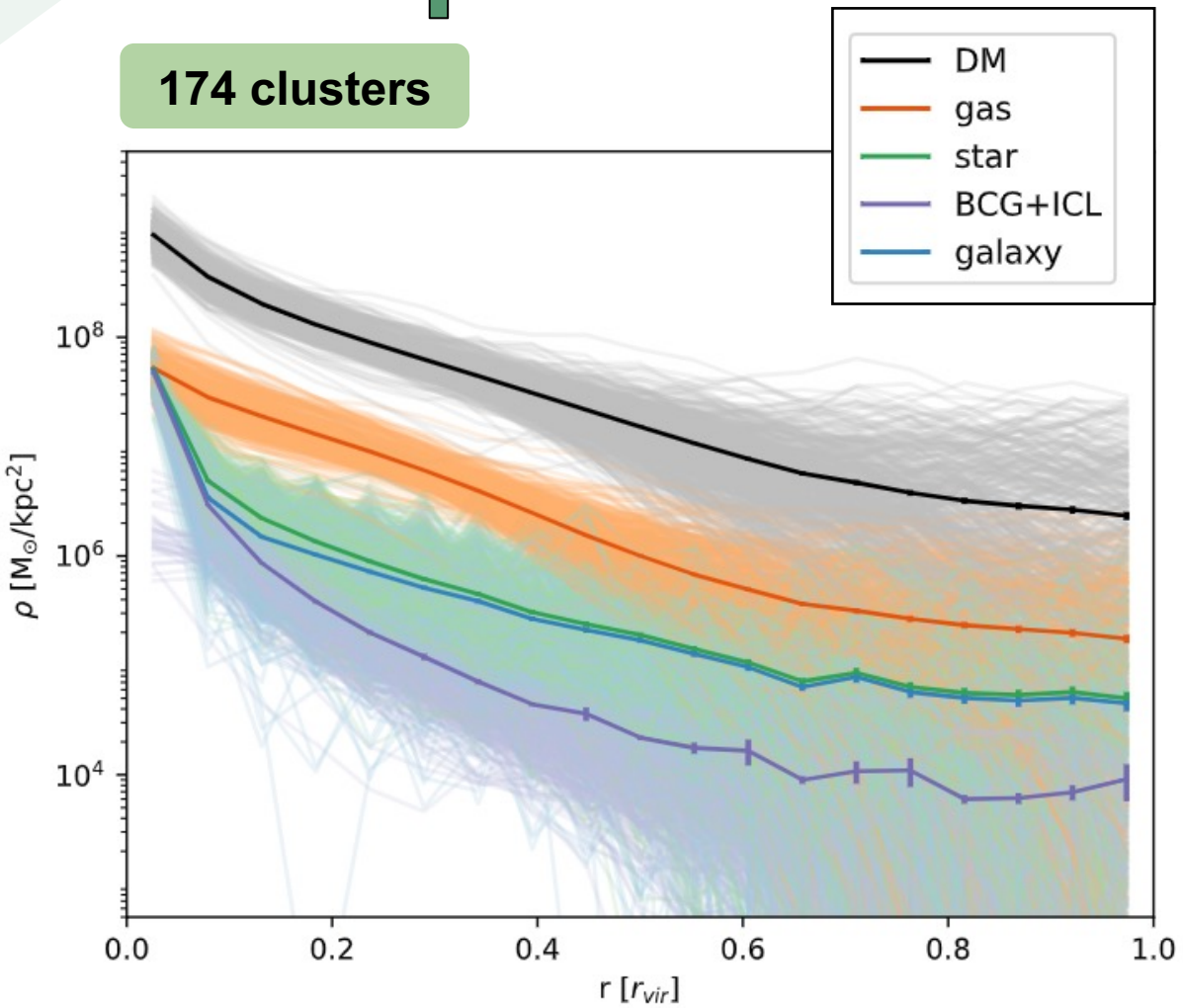
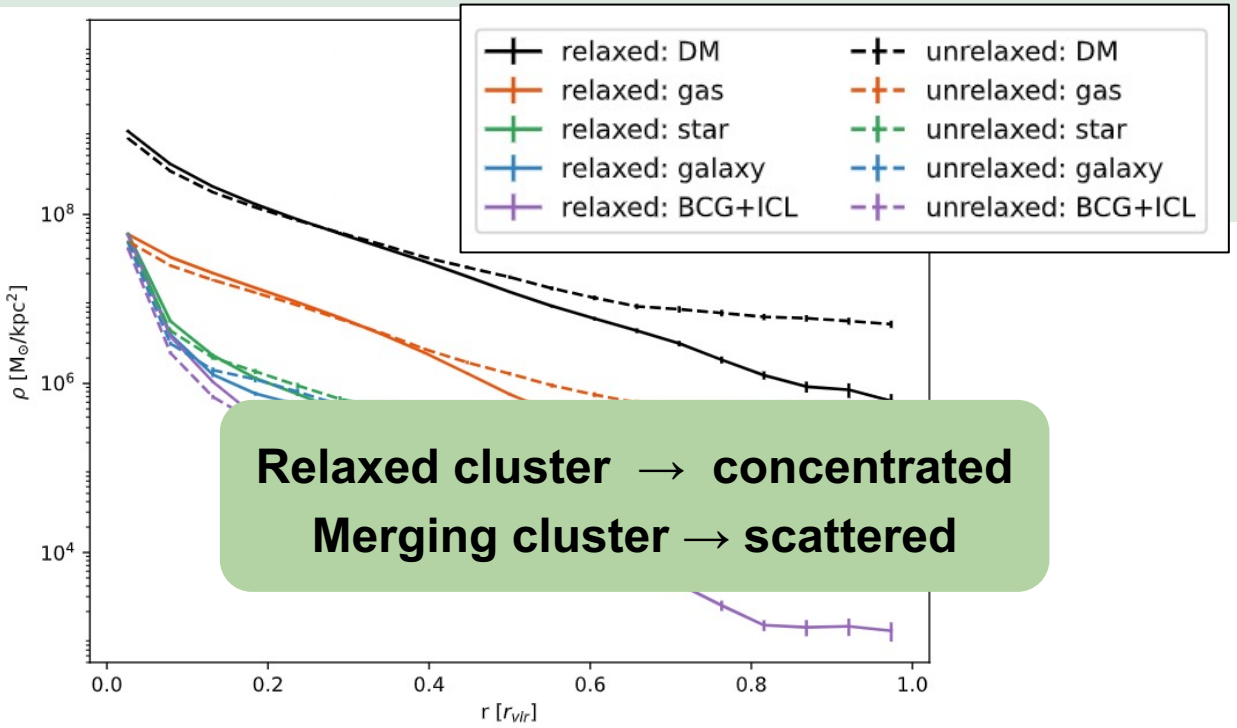


Radial Profile

174 clusters

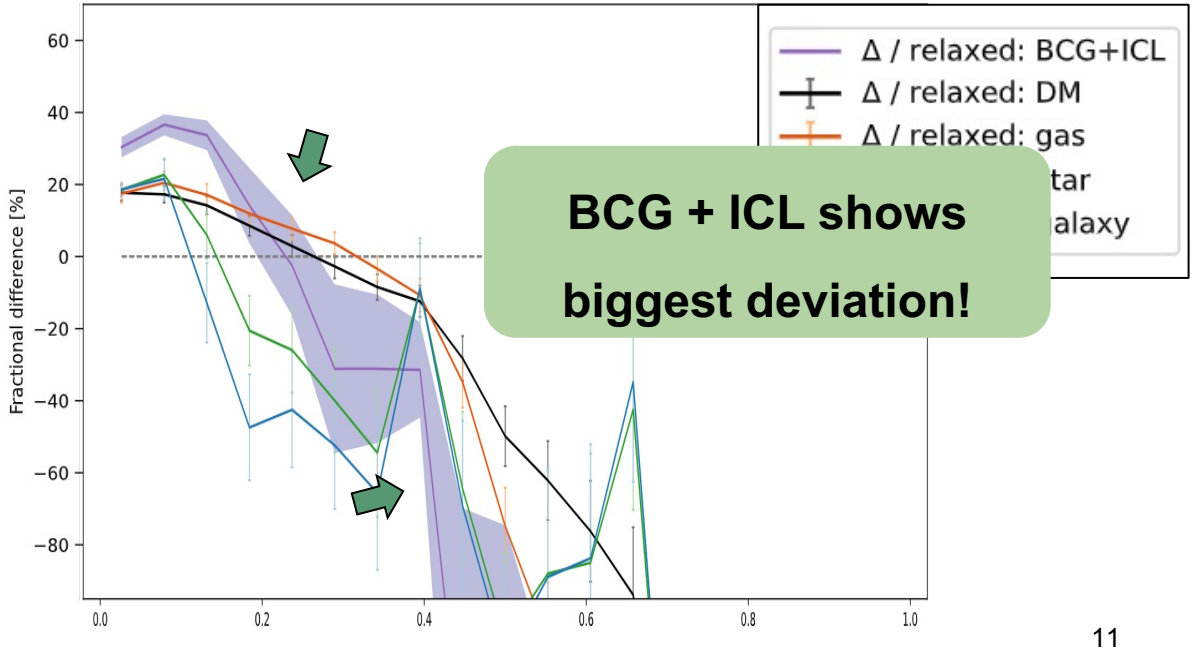
55 relaxed / 54 unrelaxed





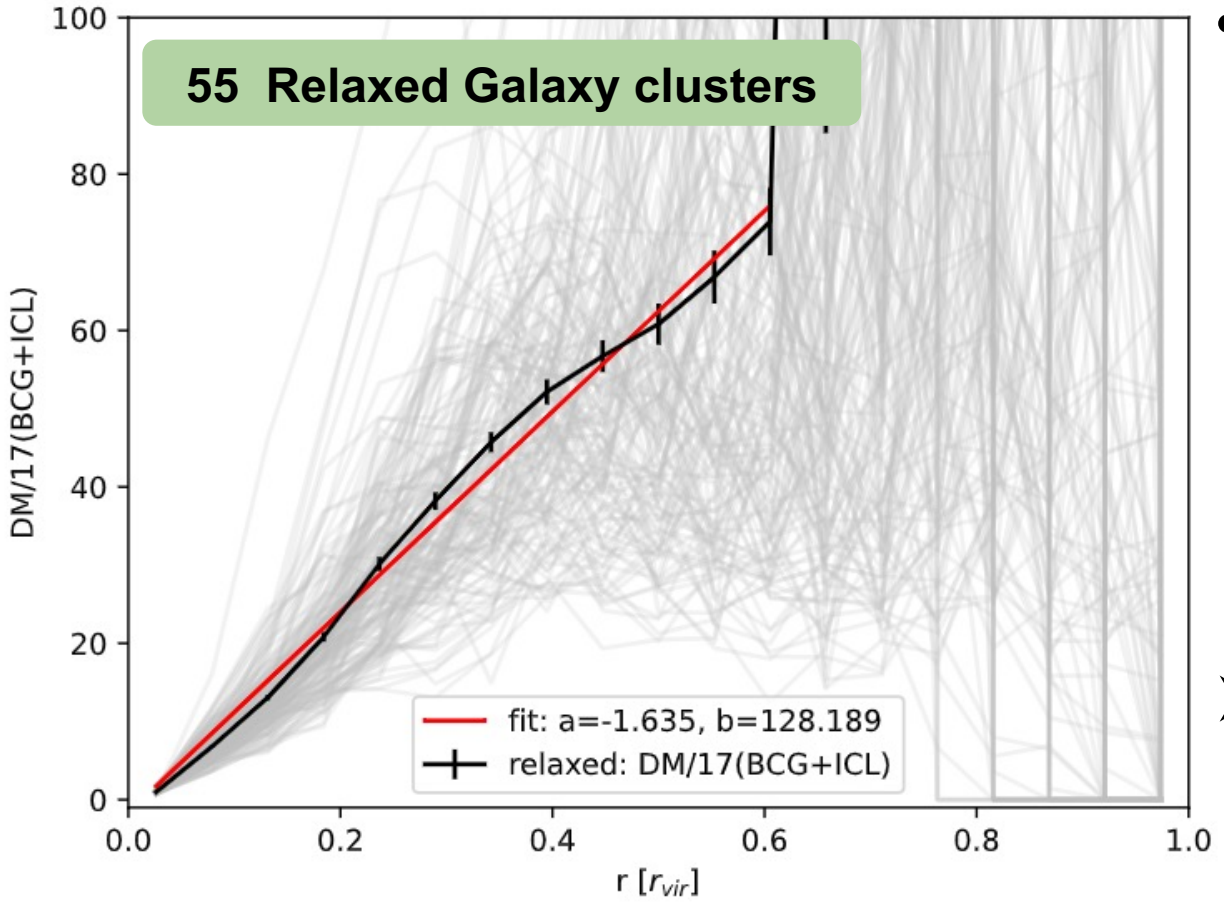
Relaxed cluster → concentrated

Merging cluster → scattered



BCG + ICL shows biggest deviation!

Recovering DM radial profile from BCG+ICL profile

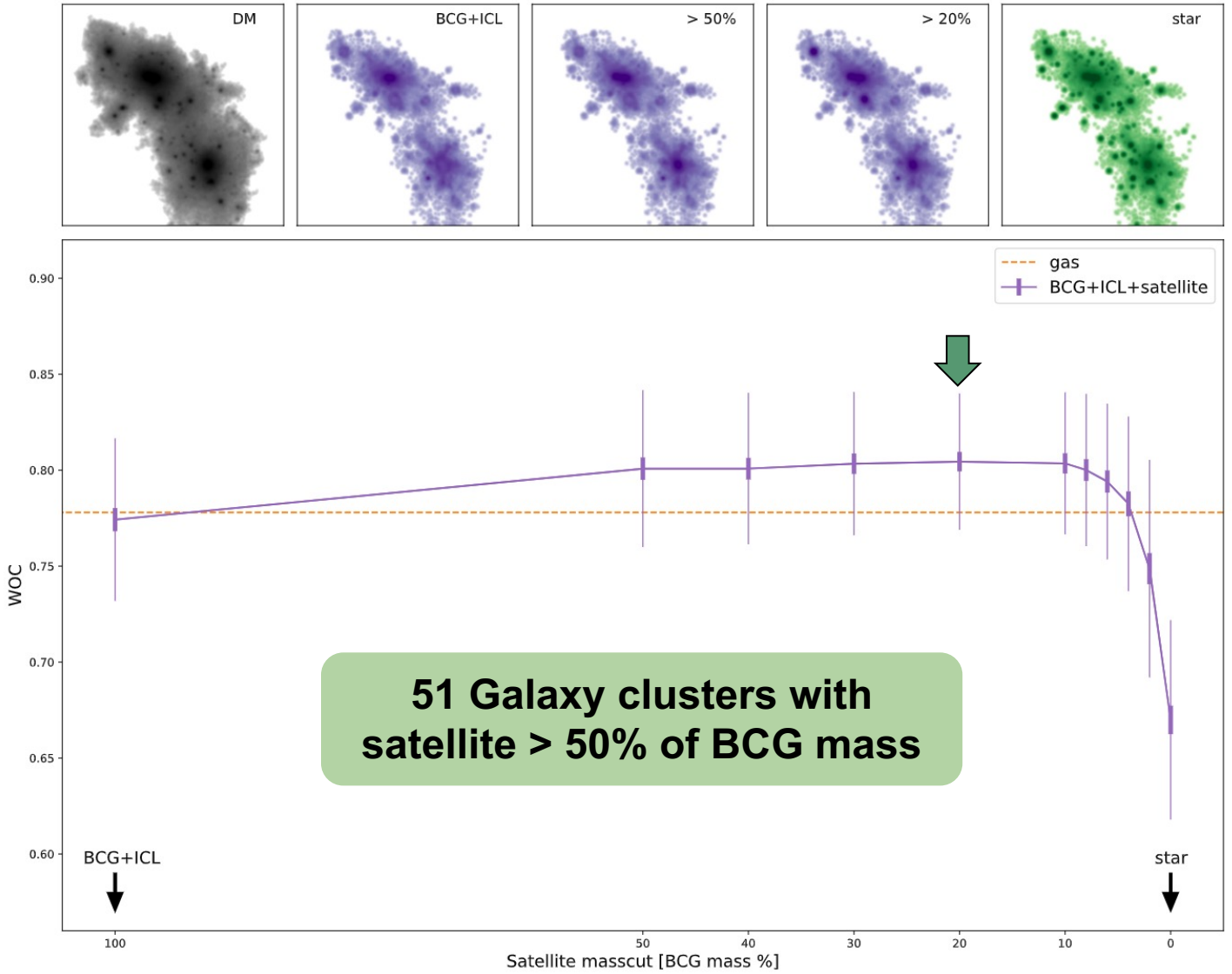


- Reconstructing DM profile from BCG+ICL profile by applying specific scaling constants and considering the radial distance from the center

➢ 1/r relation bw DM and BCG+ICL may come from “mass segregation”

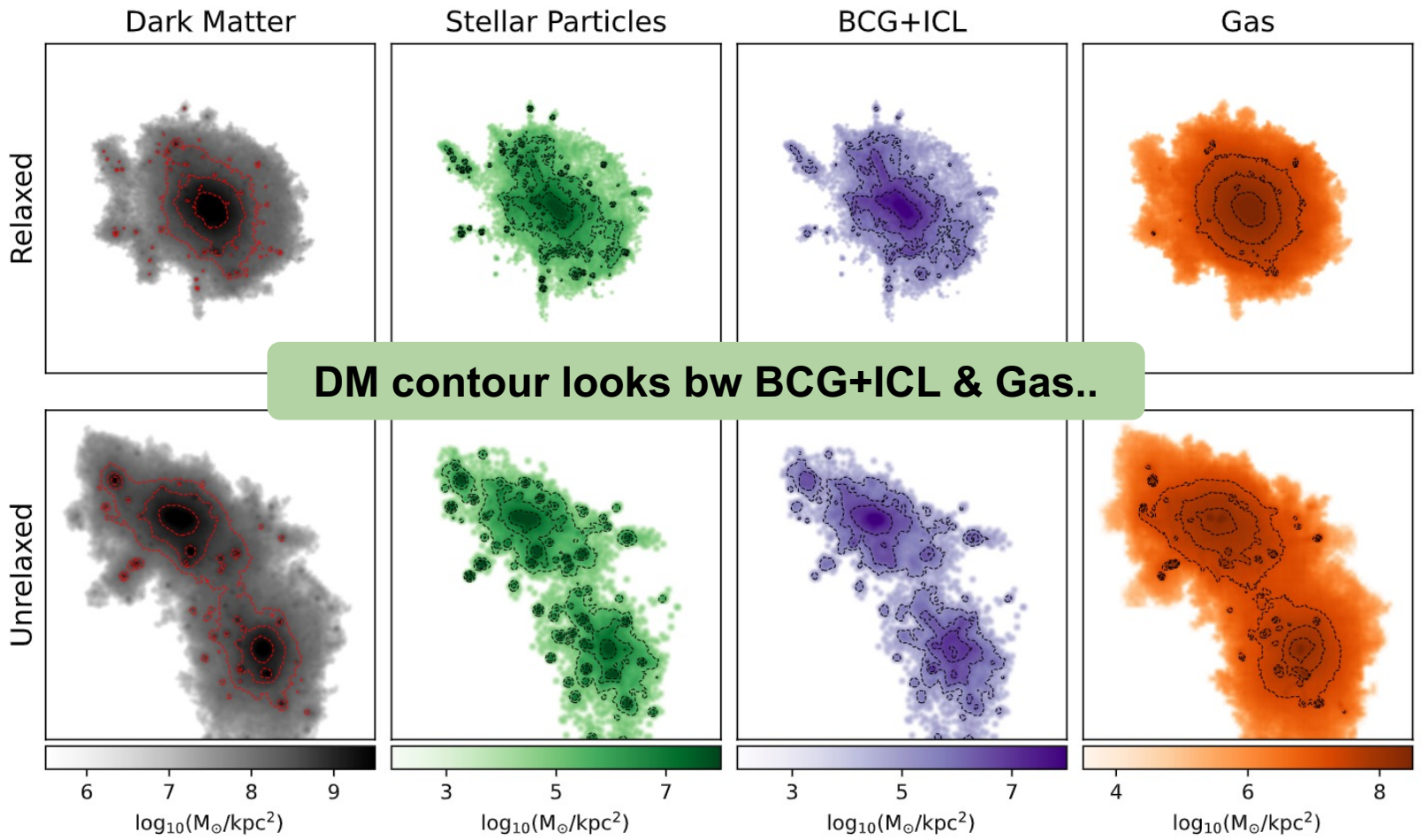
Possibilities to improve WOC

- Recipe for tracing DM in unrelaxed system
- ➢ Including massive satellite galaxies (>20% of BCG mass) together with BCG+ICL



Possibilities to improve WOC

- Tracing DM combining BCG+ICL and gas



Possibilities to improve WOC

- Tracing DM combining BCG+ICL and gas

	All 174 clusters	Relaxed 55 clusters	Middle 63 clusters	Unrelaxed 54 clusters
WOC (DM, star)	0.661	0.662	0.656	0.661
std (xy, yz, zx)	0.018	0.017	0.019	0.017
Nr. of measurement	172	55	62	53
WOC (DM, galaxy)	0.557	0.545	0.552	0.587
std (xy, yz, zx)	0.021	0.020	0.020	0.022
Nr. of measurement	80	21	30	28
WOC (DM, BCG+ICL)	0.792	0.826	0.784	0.768
std (xy, yz, zx)	0.024	0.015	0.025	0.039
Nr. of measurement	172	55	62	53
WOC (DM, gas)	0.813	0.835	0.800	0.791
std (xy, yz, zx)	0.024	0.018	0.027	0.025
Nr. of measurement	174	55	63	54
WOC (DM, BCG+ICL+gas)[a]	0.862	0.887	0.851	0.853
std (xy, yz, zx)	0.019	0.014	0.022	0.022
Nr. of measurement	174	55	63	54

Summary

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- **Gas/ BCG+ICL trace better DM than stars** (BCG+ICL+satellite galaxies).
- **WOC(DM,BCG+ICL) is high over cosmic timescale.**

➢ **BCG + ICL is good and stable tracer for DM.**

- **Relaxed** cluster has **higher WOC(DM,BCG+ICL) / WOC(DM,Gas).**
- **WOC(DM,BCG+ICL) drops** with **major merging** event and **recovers afterwards.**

➢ **BCG + ICL is sensitive indicator for Cluster Dynamics.**

- Let's apply it on observational survey data of **K-DRIFT and Rubin**! ☺

Thank You!

Jaewon Yoo ▪ ICL ▪ Galaxy Cluster