

# A Weather Forecast for Galaxy Clusters in IllustrisTNG

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Questions addressed in this talk:

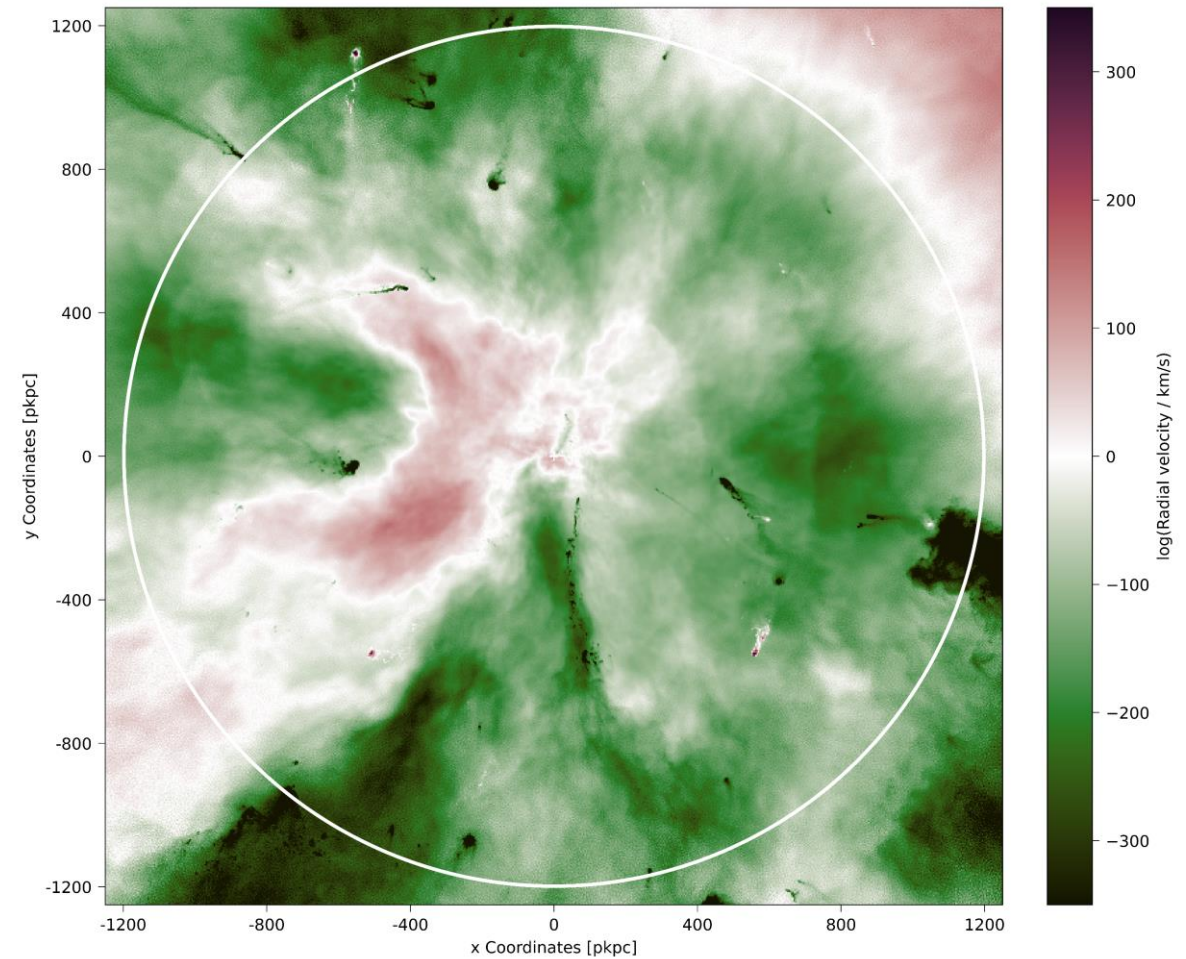
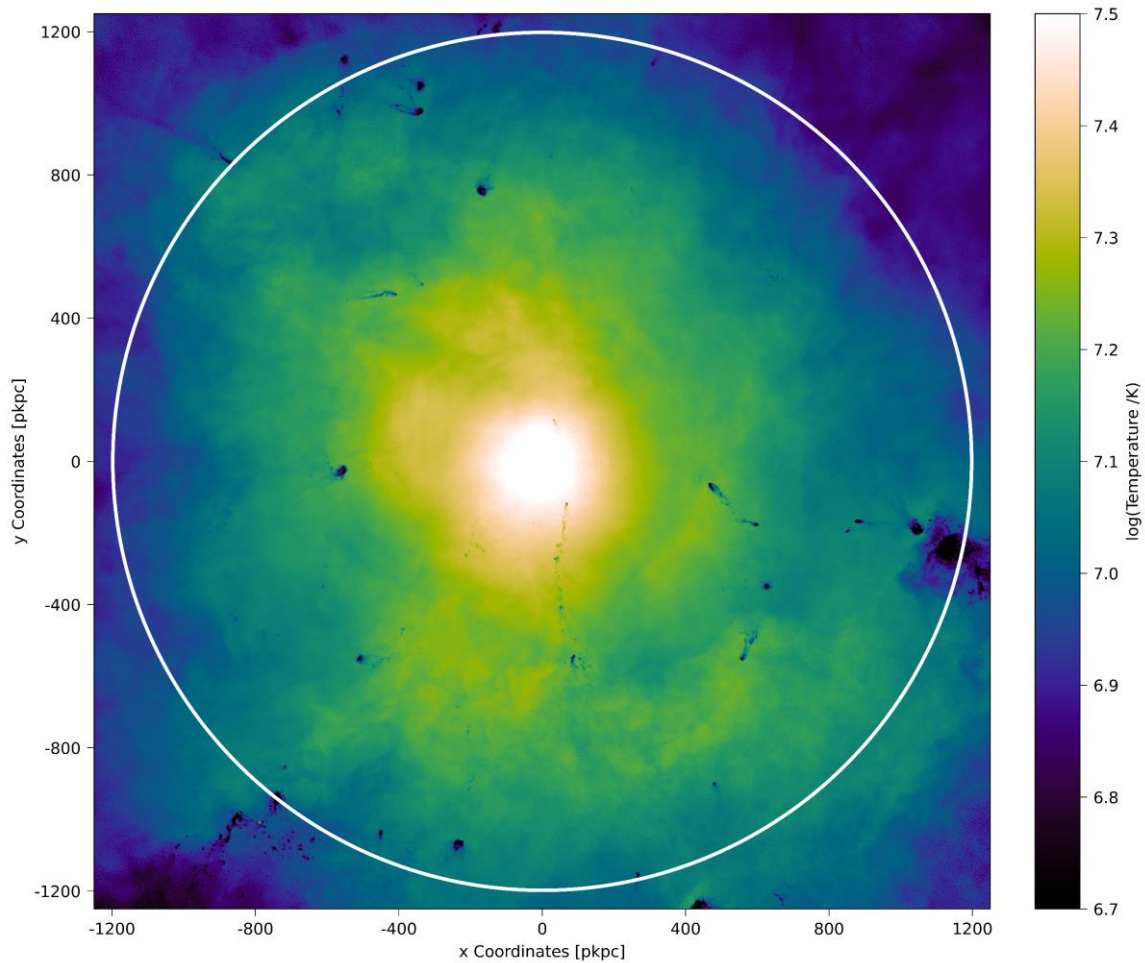
1. Is the ICM of the Virgo-like Cluster in TNG50 multiphase?
2. How does the cold gas in this cluster evolve?

The global structure of the cluster represented by projections of temperature and radial velocity.

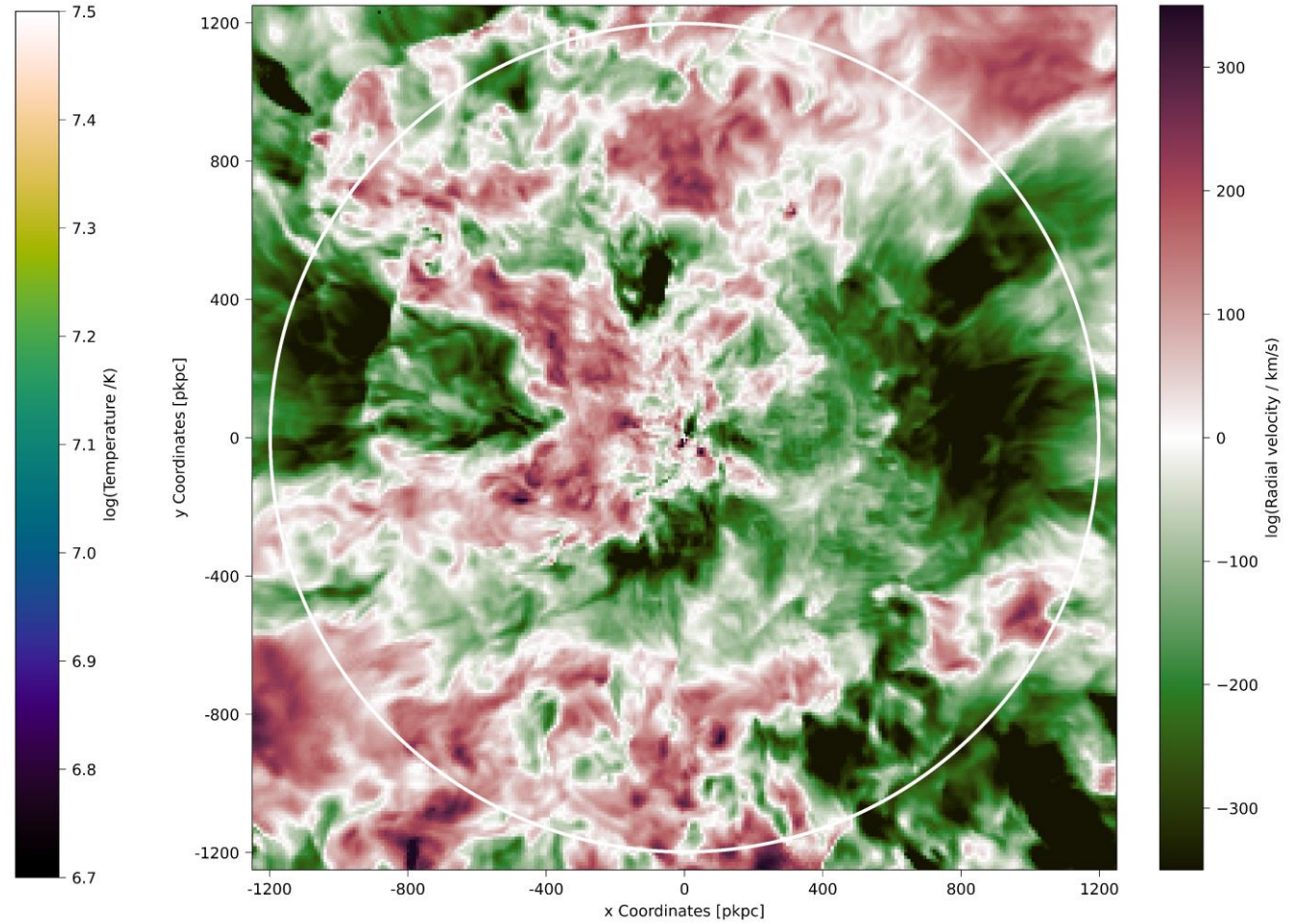
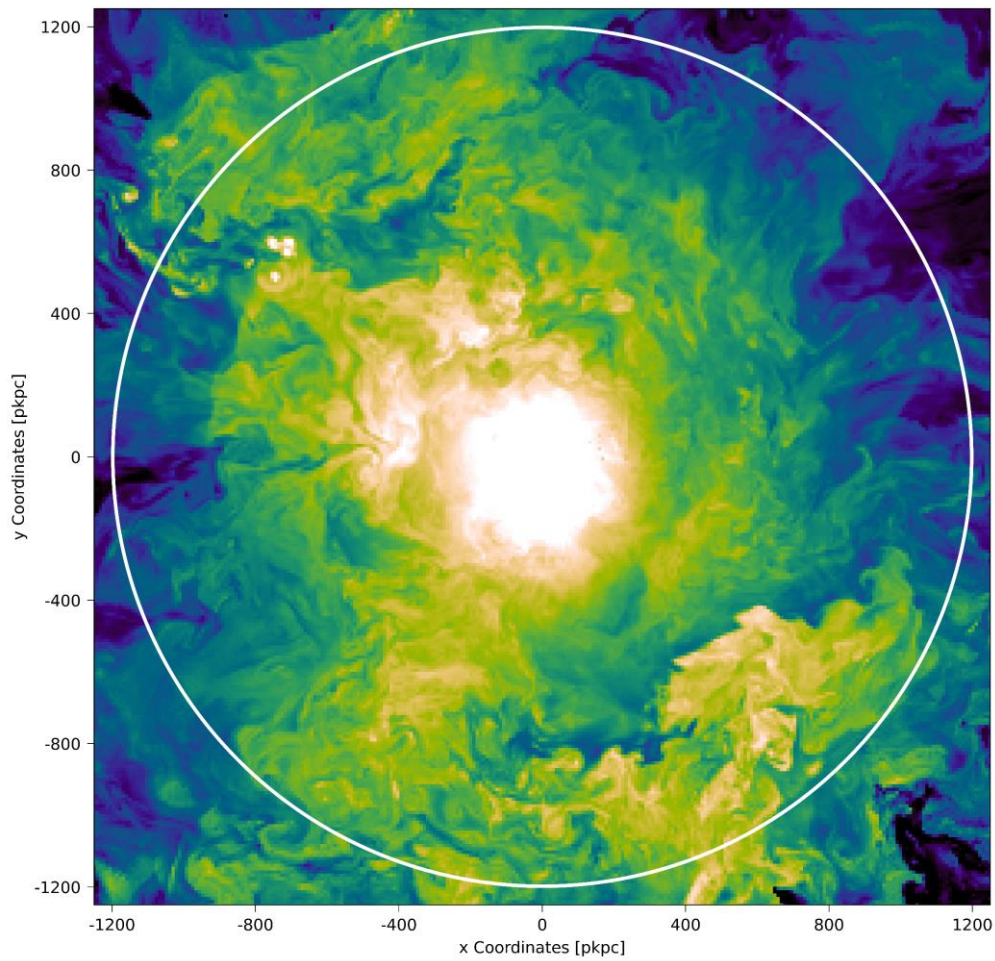
$$M_{200} = 10^{14.26} M_{\odot}$$
$$r_{200} = 1197 \text{ kpc}$$

$$T_{200} = 2.4 \cdot 10^7 \text{ K}$$
$$M_{\text{star}} = 5.7 \cdot 10^{11} M_{\odot}$$

Lehle+(in prep)

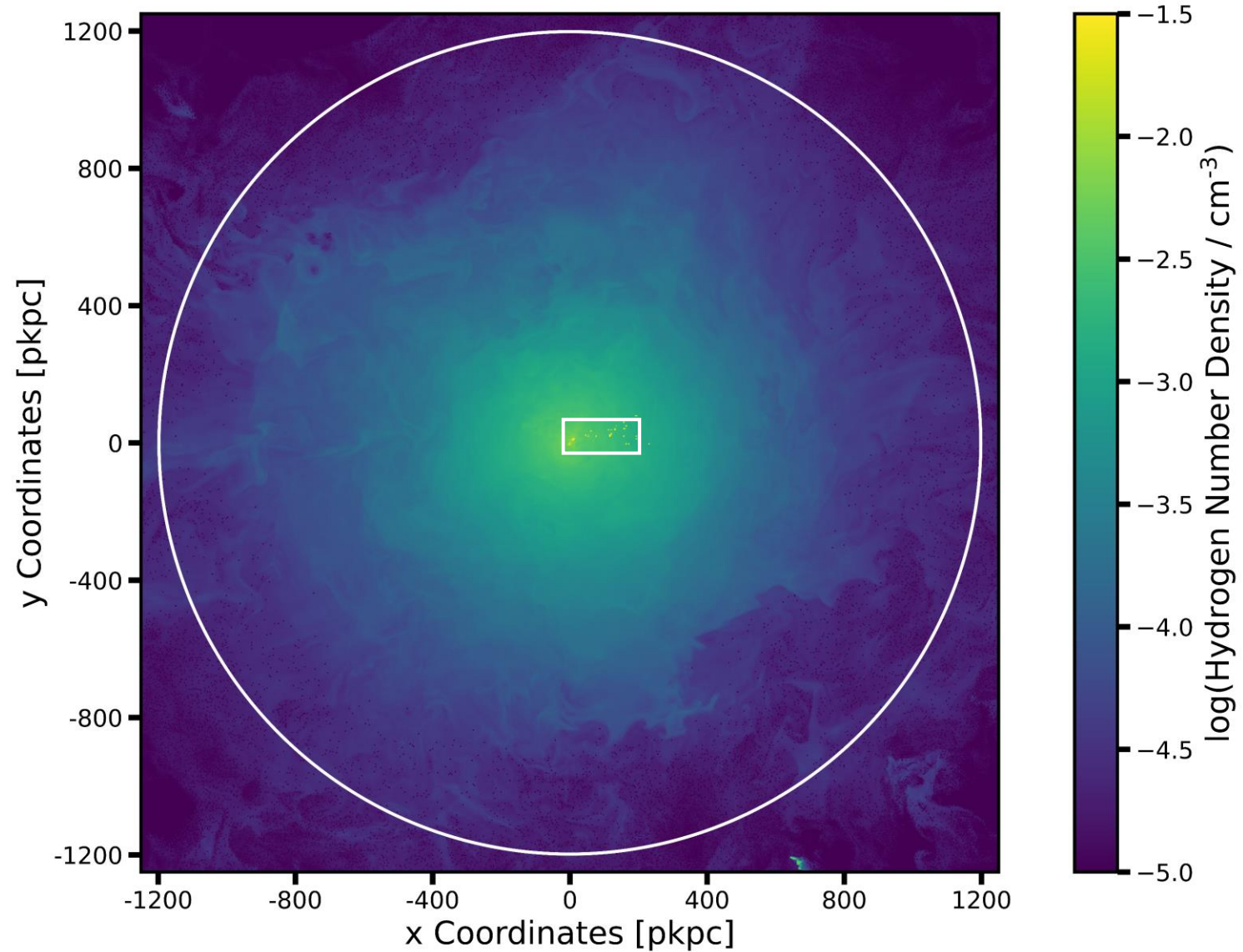


20 kpc deep slices through the cluster reveal the complex structure of the gas.

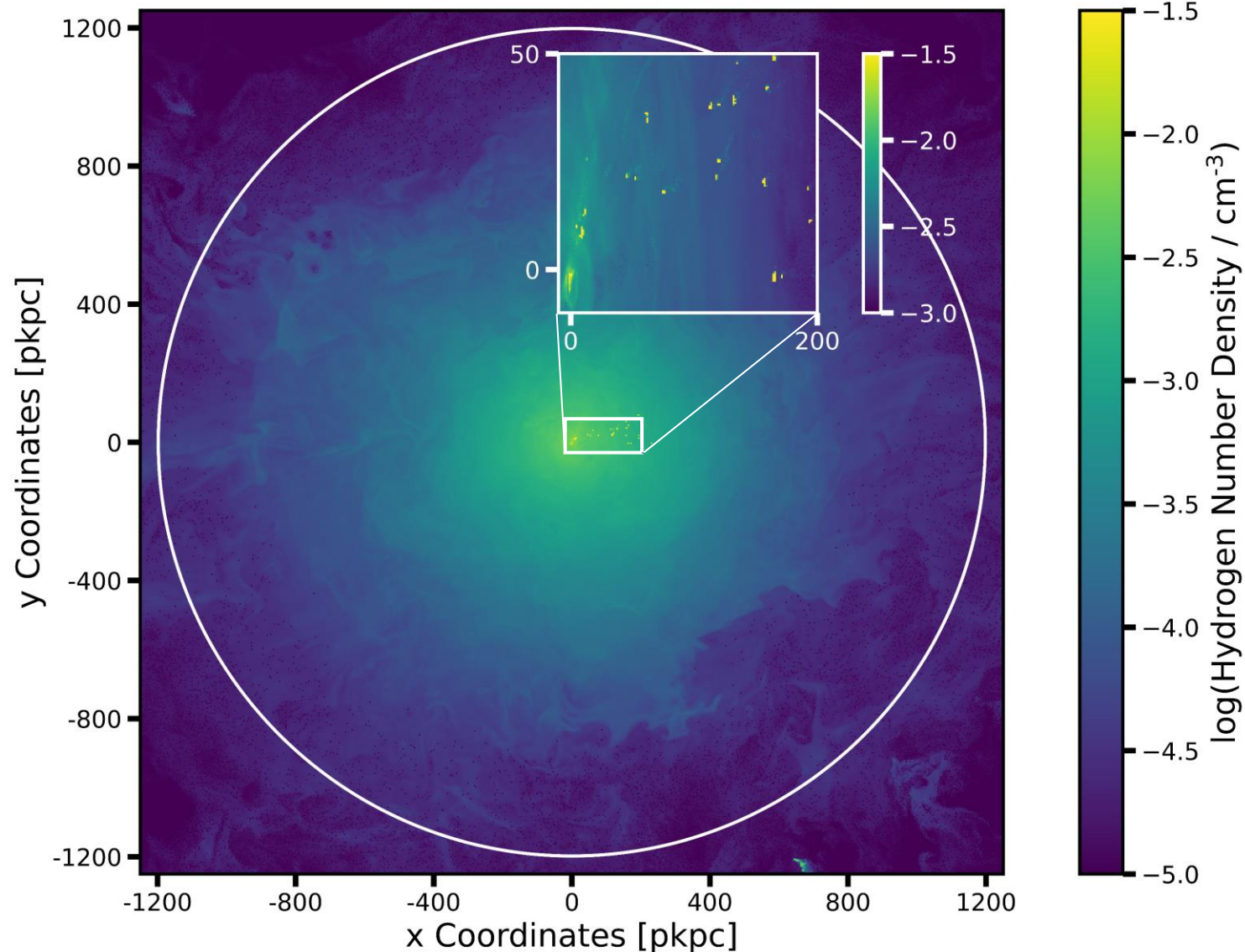


Lehle+(in prep)

Central high-density clouds are seen in the map of the hydrogen number density.



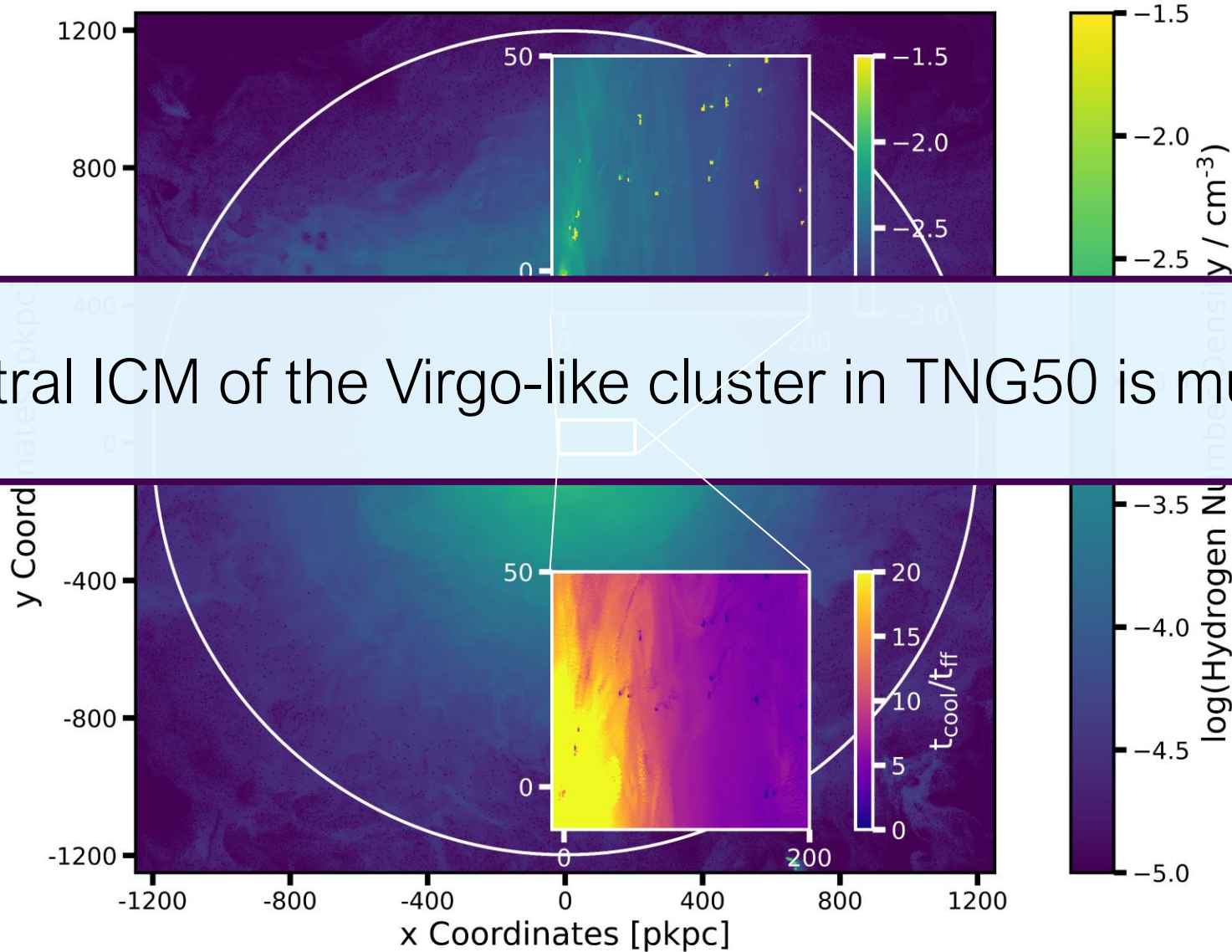
Central high-density clouds are seen in the map of the hydrogen number density.



Cloud formation scenarios:

- RAM pressure stripping from satellites
- galactic outflows
- condensation of entropy perturbations

The central clouds are formed by condensation of entropy perturbations of gas with  $t_{\text{cool}}/t_{\text{ff}} < 10$ .

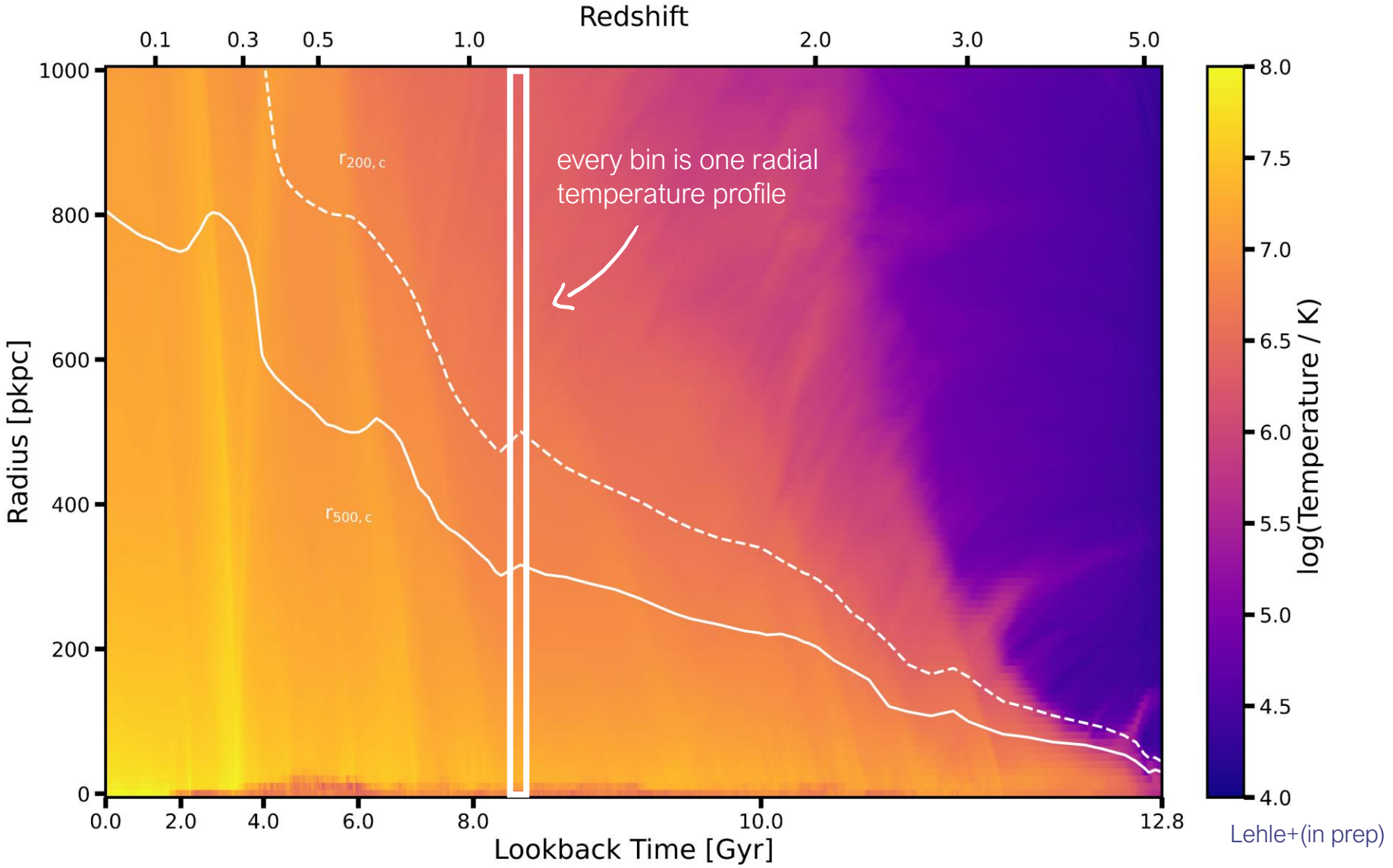


The central ICM of the Virgo-like cluster in TNG50 is multiphase.

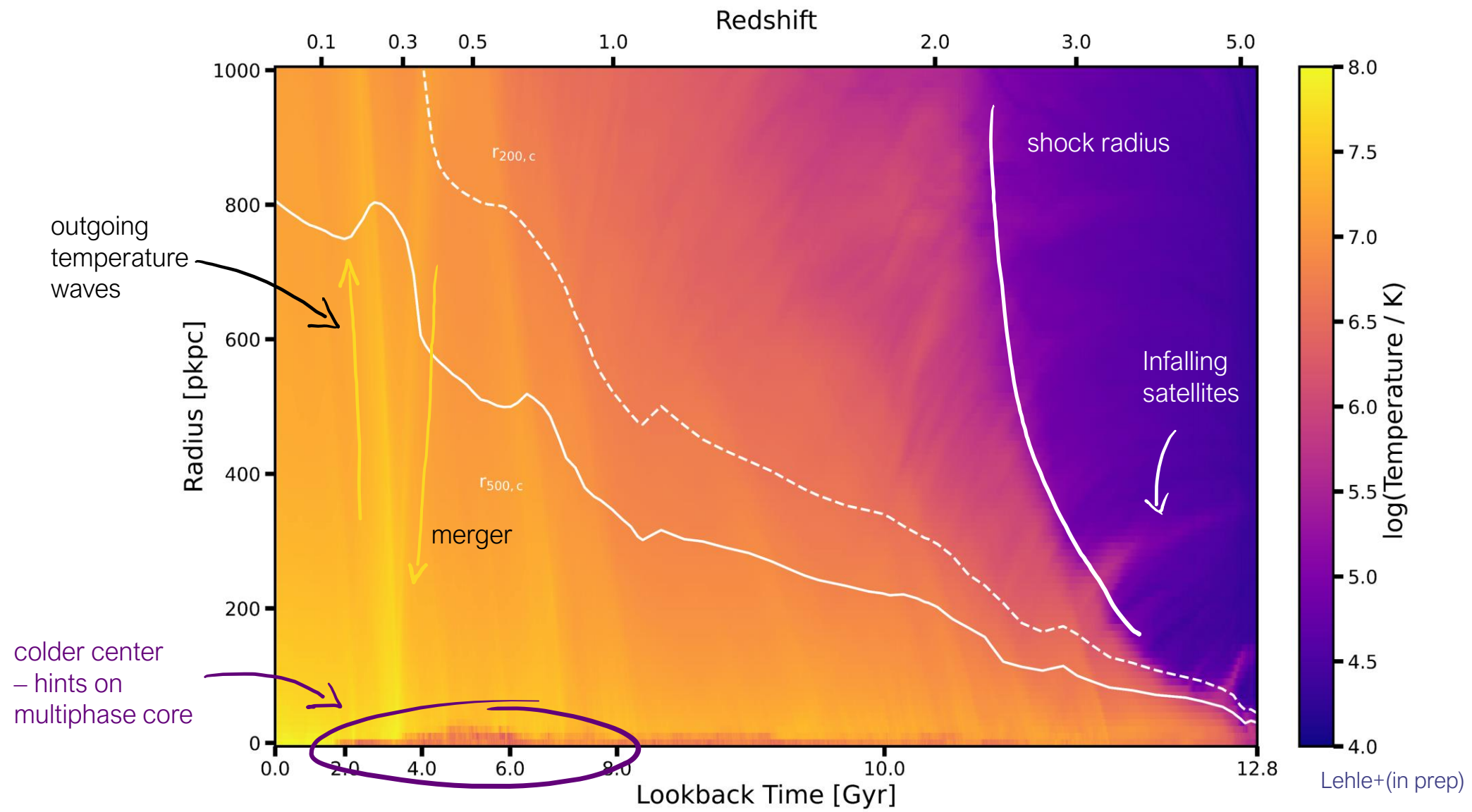
2. How does the cold gas in this cluster evolve?



Everything Everywhere All at Once: Evolution of the temperature profile.



# Everything Everywhere All at Once: Evolution of the temperature profile



## 2. How does the cold gas in this cluster evolve?

We explore...

- ... specific spatial region: core of the cluster
- ... specific mechanism: AGN feedback

2. How does the cold gas in this cluster evolve?

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... specific spatial region: core of the cluster

... specific mechanism: AGN feedback

2. Can AGN feedback influence the multiphase nature of the core and change the core state?

We use cool core-ness as a tracer for multiphase gas.

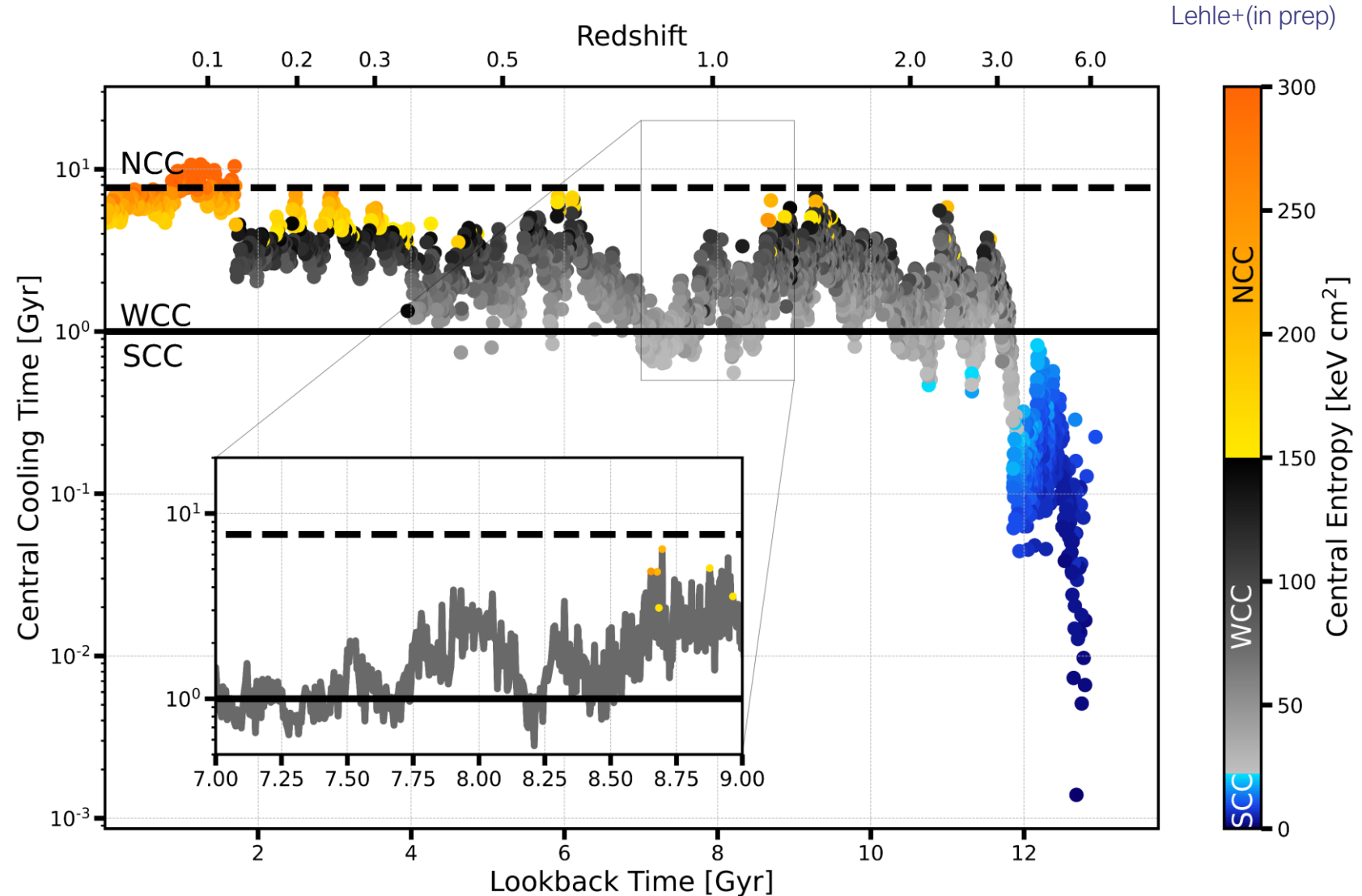
Cool core criteria:

Mass-weighted mean of **cooling time, entropy** or **electron number density** within aperture of  $r = 0.012 r_{500}$

The categorization is based on observations and values are taken from Hudson+2010.

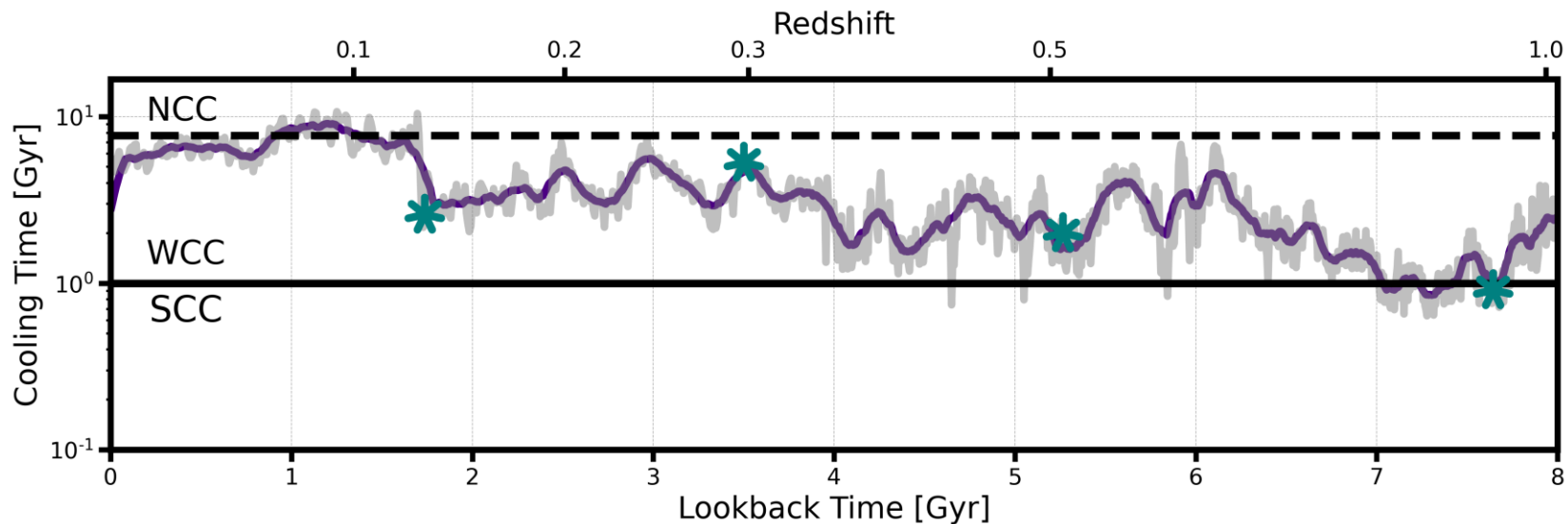
Two trends are visible:

- Overall increase of  $t_{\text{cool}}$
- Variations on times scales  $< 1\text{Gyr}$



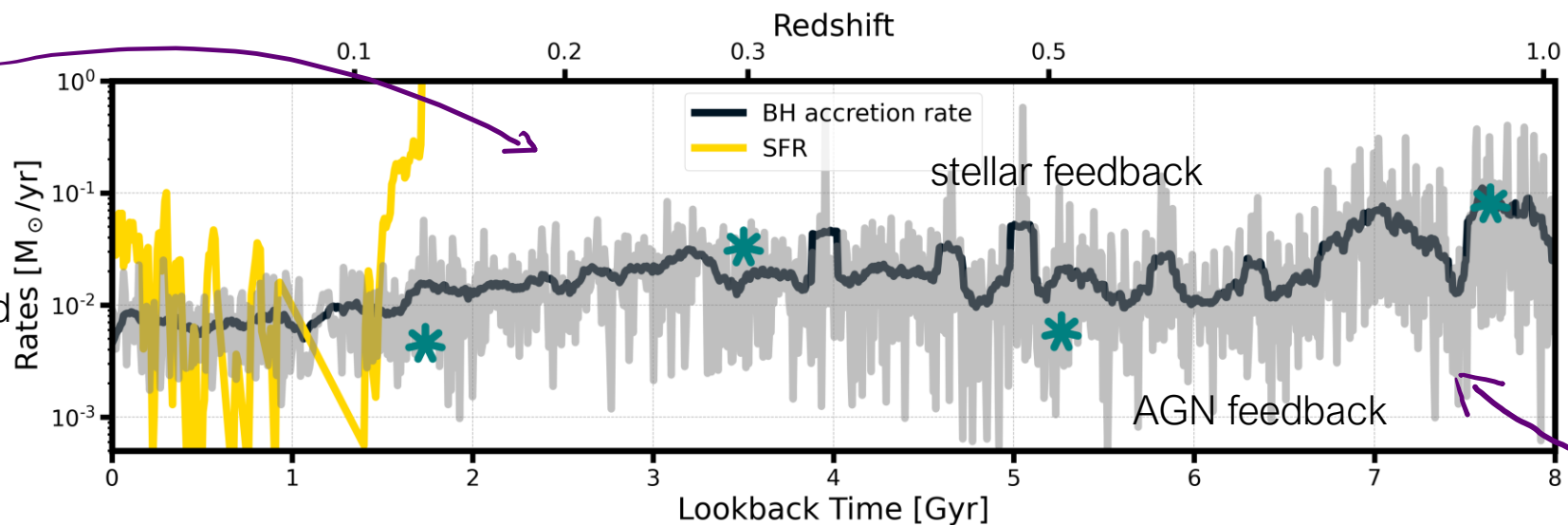
Core state evolution is dominated by AGN feedback.

smoothed  
central  $t_{\text{cool}}$   
oscillates with  
period  $< 1\text{Gyr}$



\* 4 most massive  
BH-BH mergers

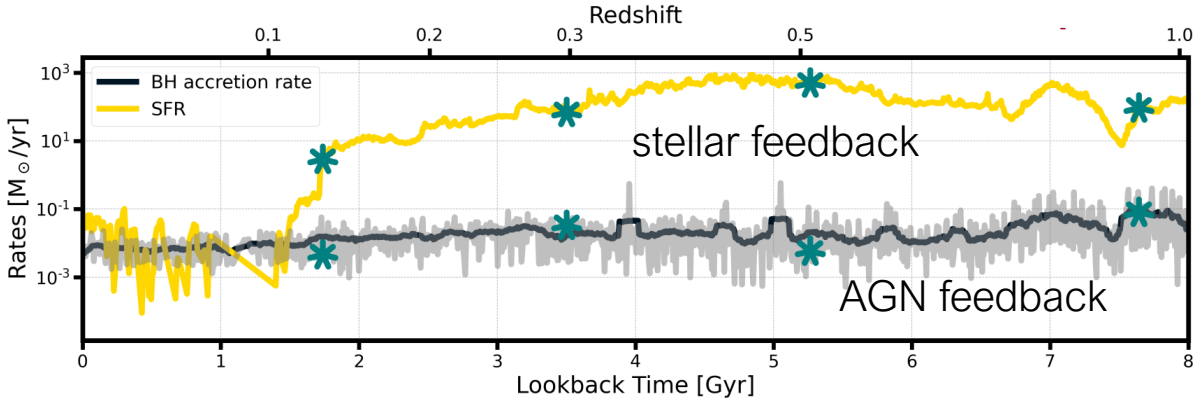
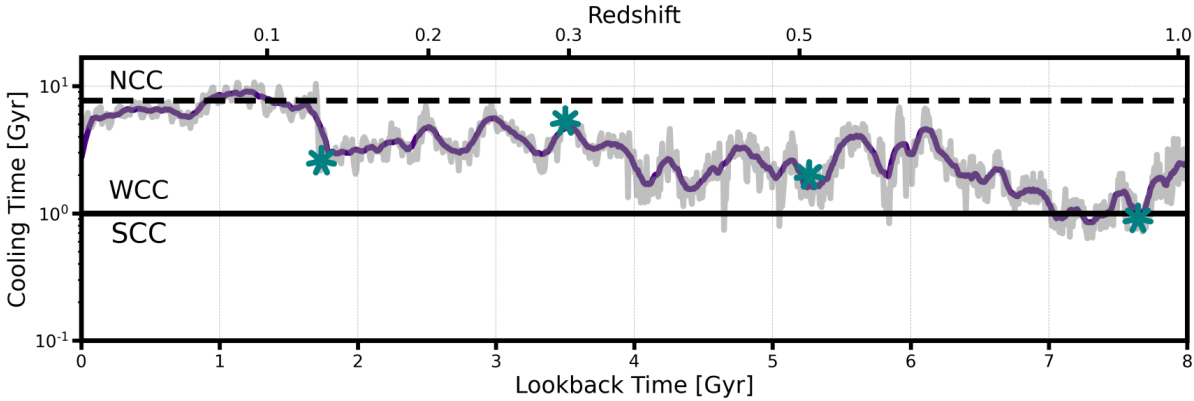
SFR does not  
oscillate that  
strongly  
→ stellar feedback  
barely correlated  
with  $t_{\text{cool}}$



BH accretion rate  
shows similar  
oscillations as  $t_{\text{cool}}$   
→  $t_{\text{cool}}$  and AGN  
feedback  
correlated

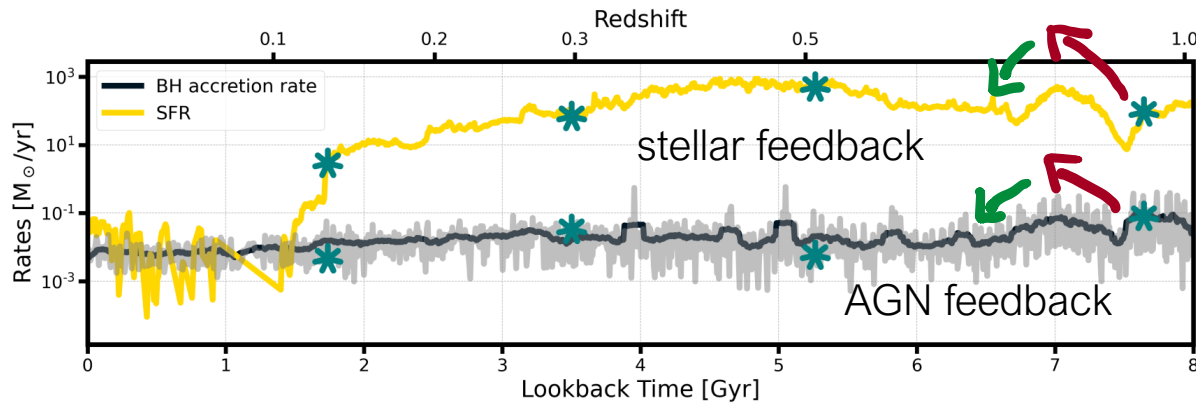
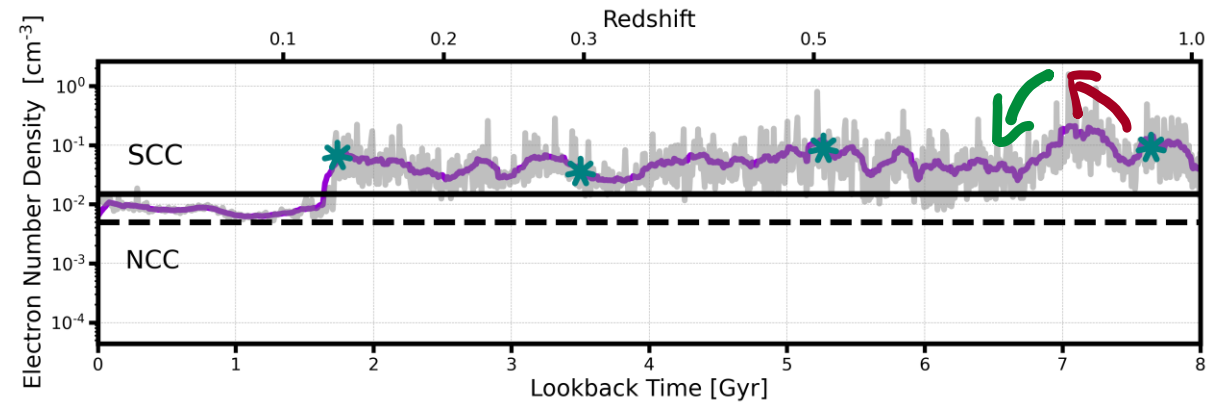
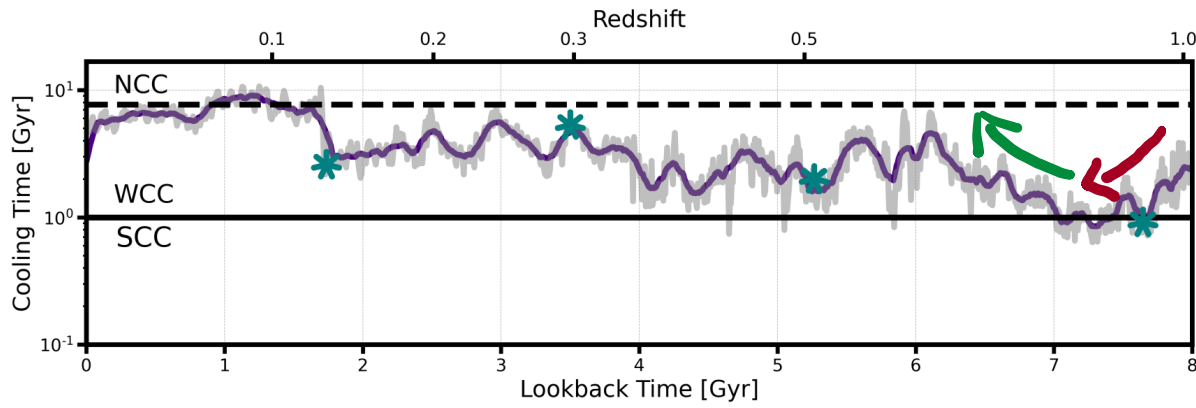
The core of the cluster shows signs of self-regulated feedback.

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The core of the cluster shows signs of **self-regulated feedback**.

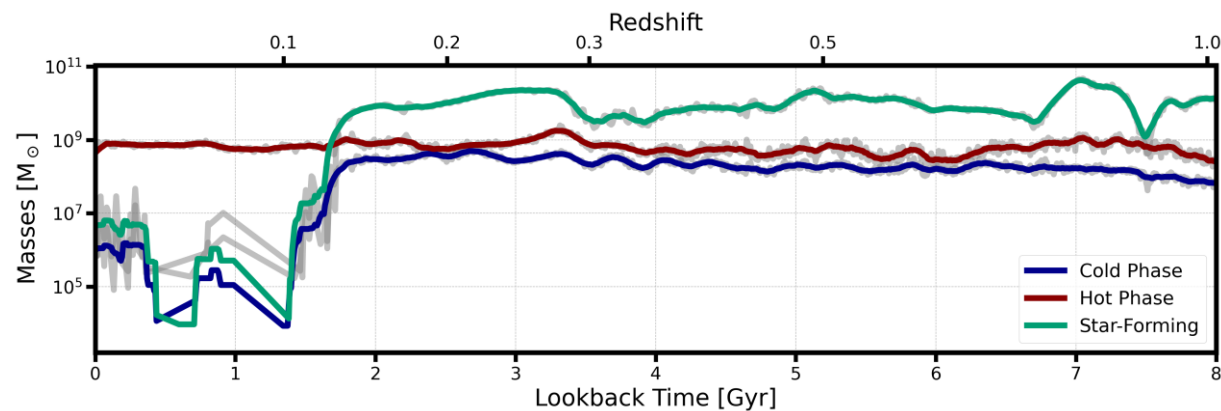
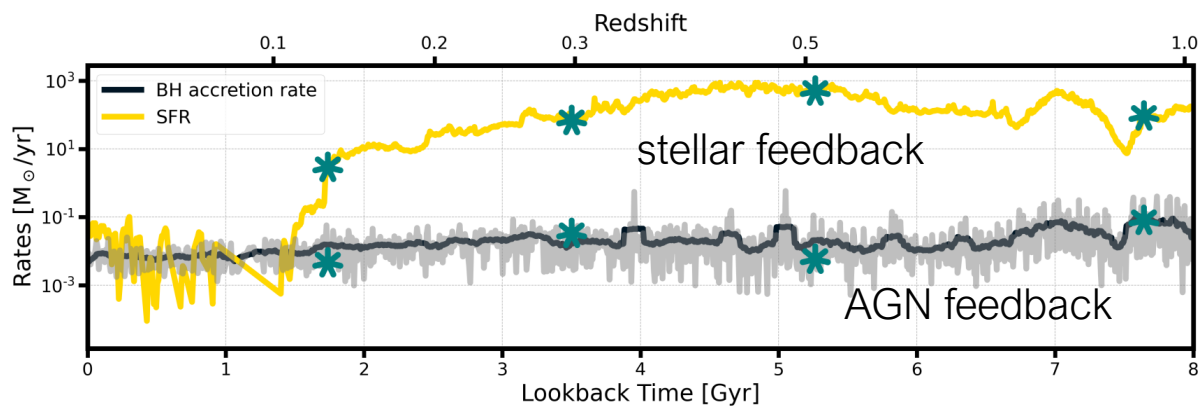
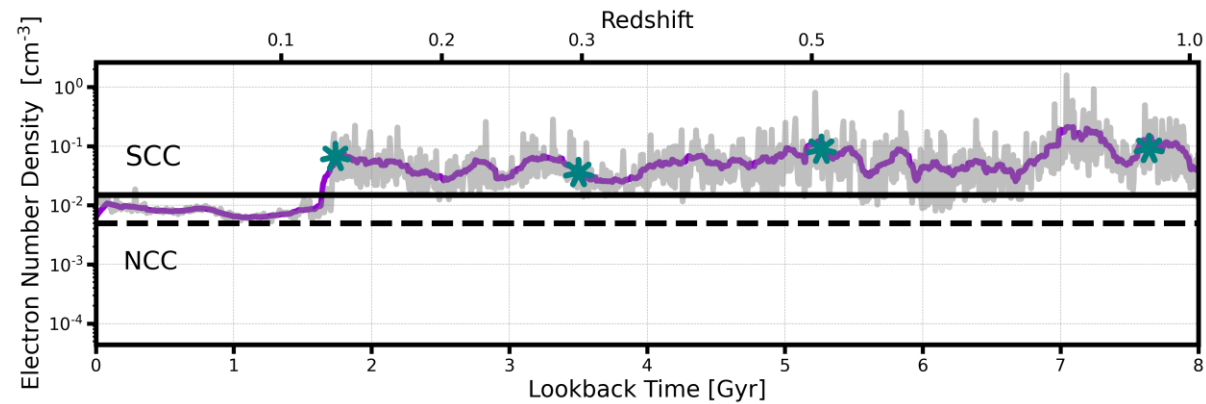
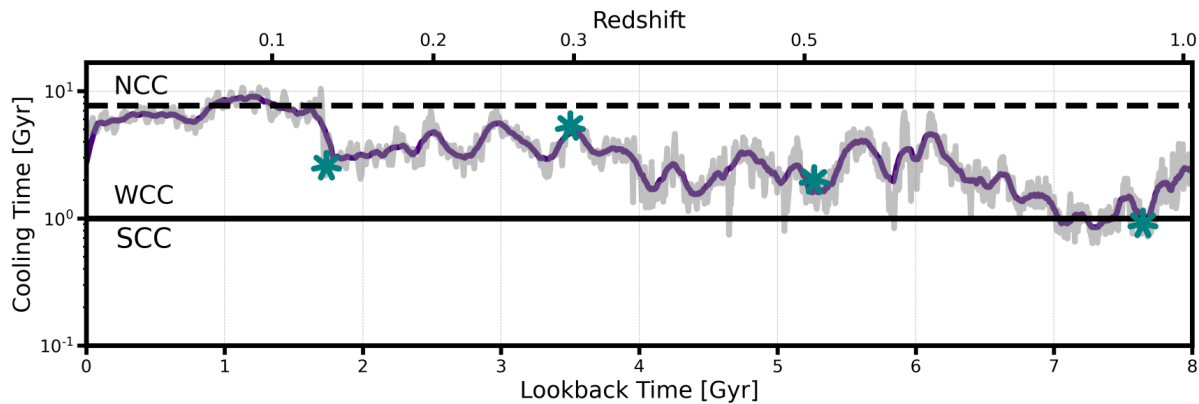
✿ 4 most massive BH-BH mergers





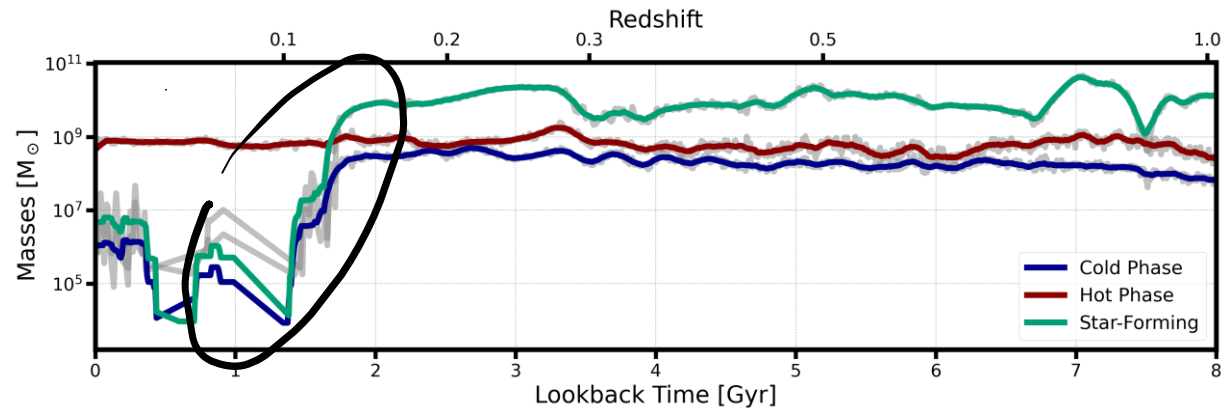
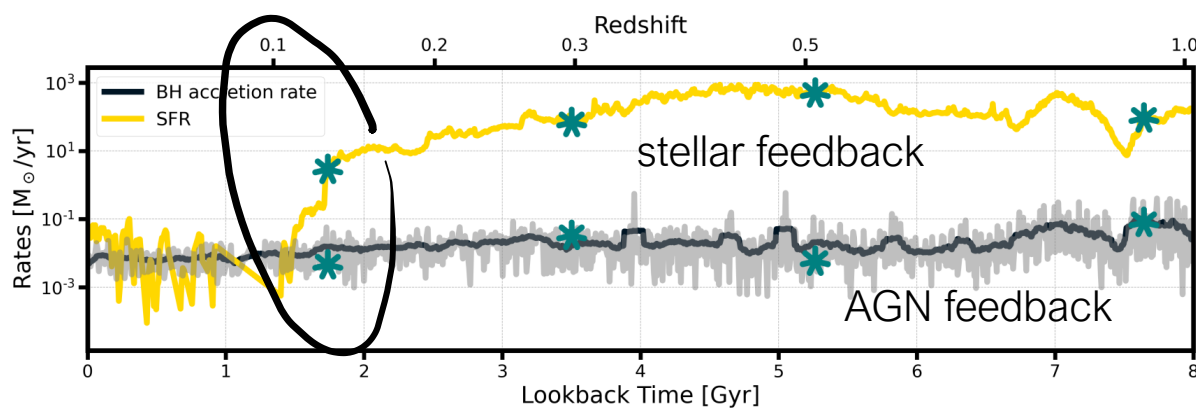
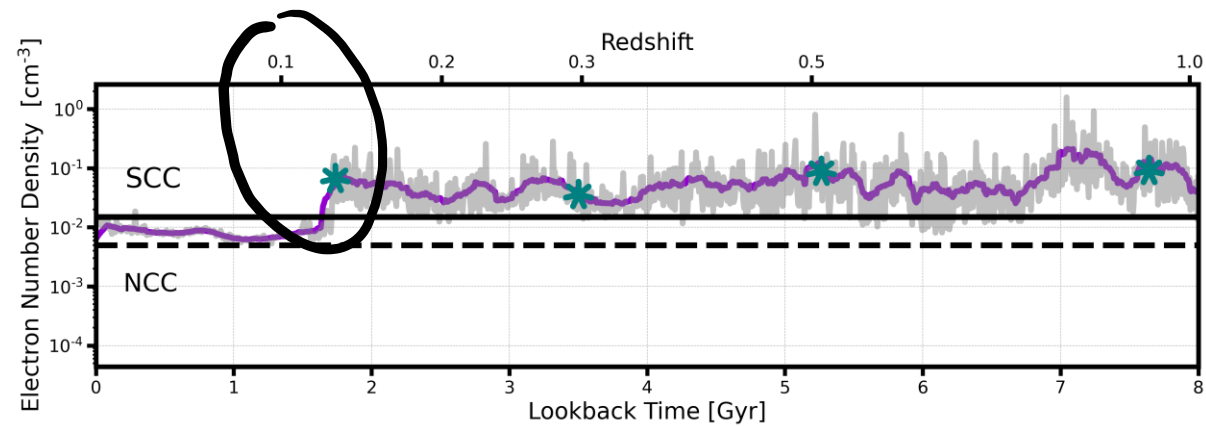
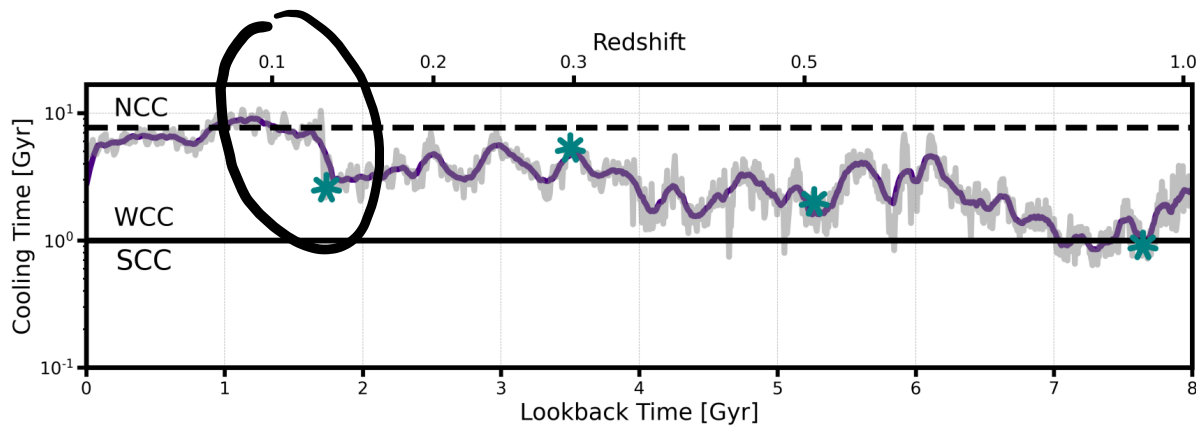
The cluster has a **multiphase core** during SCC/WCC phase.

✿ 4 most massive BH-BH mergers



Last merger finalizes the evolution from CC to NCC.

✿ 4 most massive BH-BH mergers

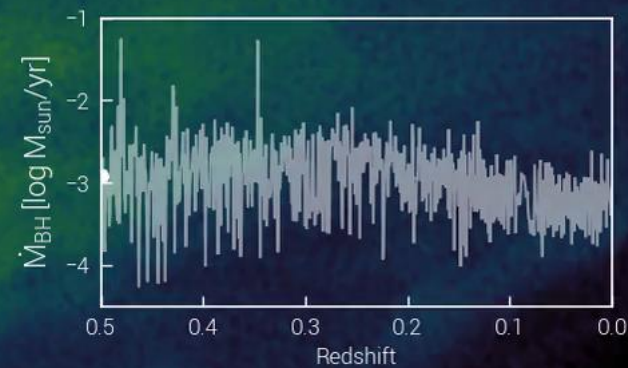


80 ckpc

$z = 0.5$

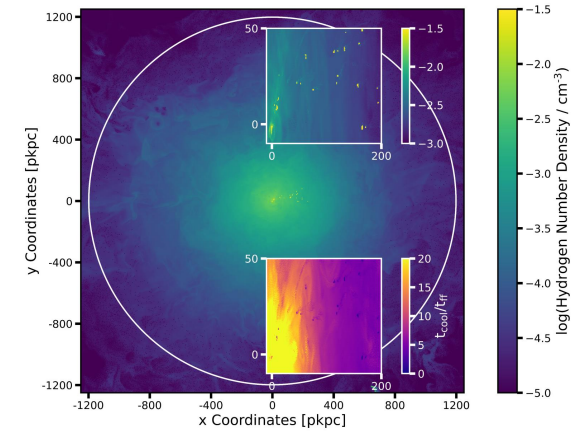
$\Delta t = 5189.2 \text{ Myr}$   
 $M_{\text{BH}} = 9.5 M_{\text{sun}}$   
 $\log \dot{M}_{\text{BH}} = -1.9 M_{\text{sun}}/\text{yr}$

Video Credits: Dylan Nelson



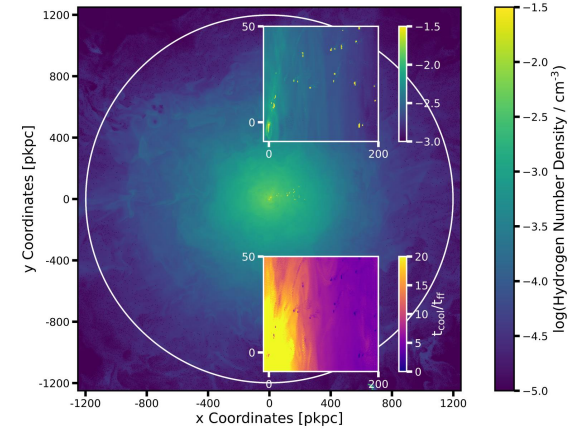
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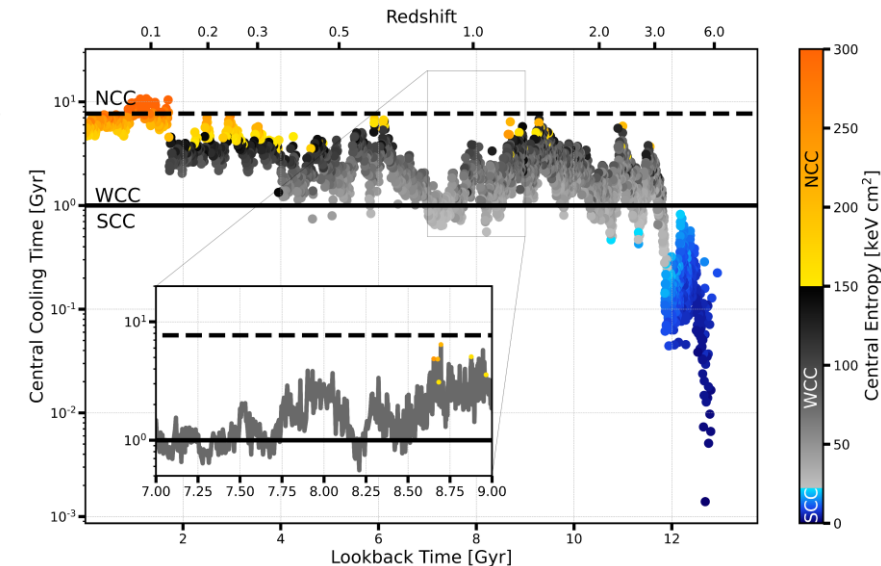
1. Is the ICM of the Virgo-like Cluster in TNG50 multiphase?  $\rightarrow$  Yes
2. Can AGN feedback influence the multiphase nature of the core and change the core state?



$\rightarrow$  Used cool core-ness as a tracer for multiphase gas

$\rightarrow$  The BH can influence the core state of the cluster by lifting/lowering  $t_{\text{cool}}$

$\rightarrow$  The final transition to a NCC is in this case accomplished by a merger





That's the weather for today.

Thank you for your interest.