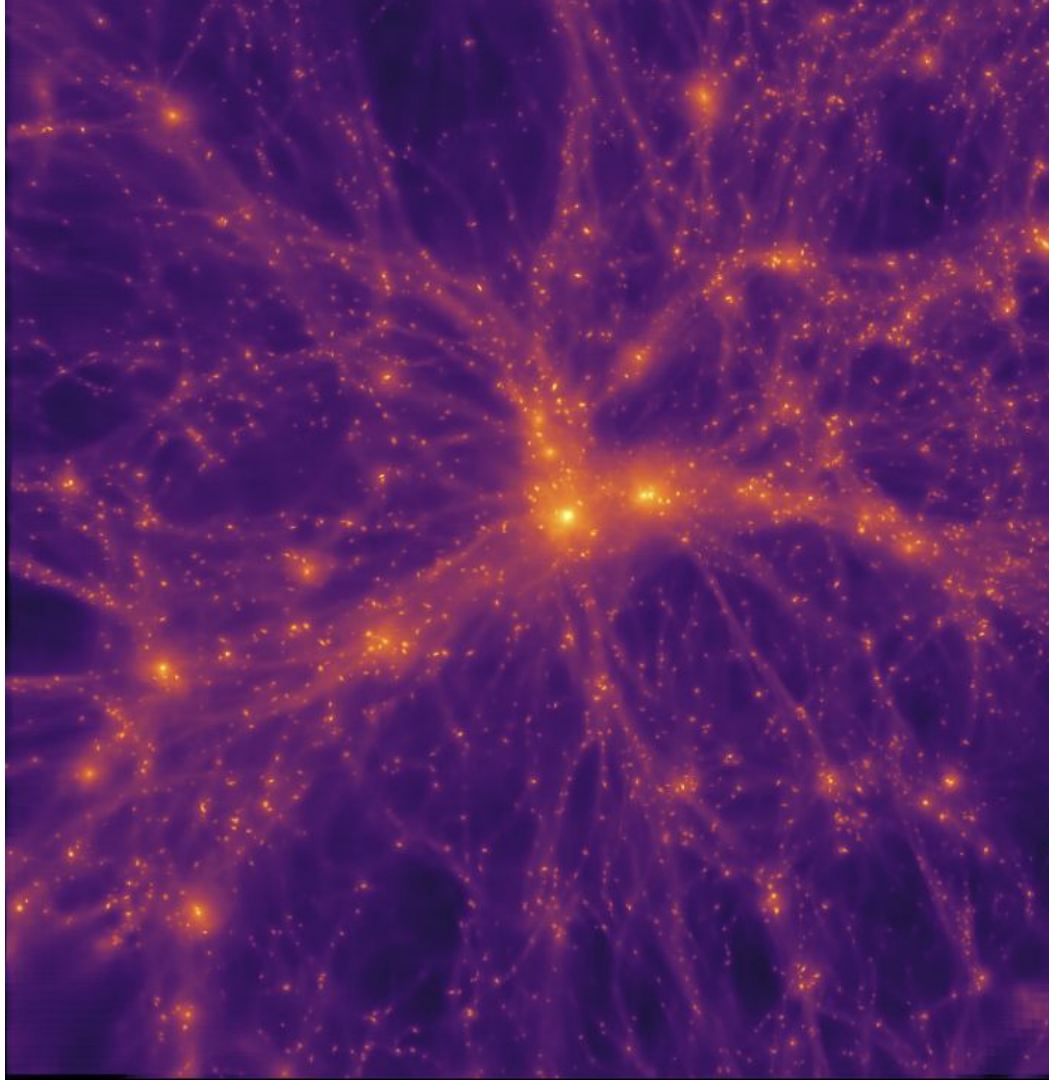


The ADELINe suite: Simulations of galaxy clusters in Λ CDM dark energy models

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With **Amandine Le Brun &
Pier-Stefano Corasaniti**



The Λ CDM model

– The concordance model of cosmology

Cosmological constant Λ (dark energy)

+

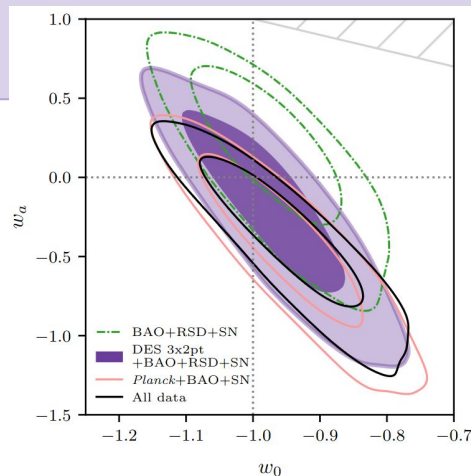
CDM (Cold Dark Matter)

Λ is responsible for the acceleration of the expansion of the Universe at late time

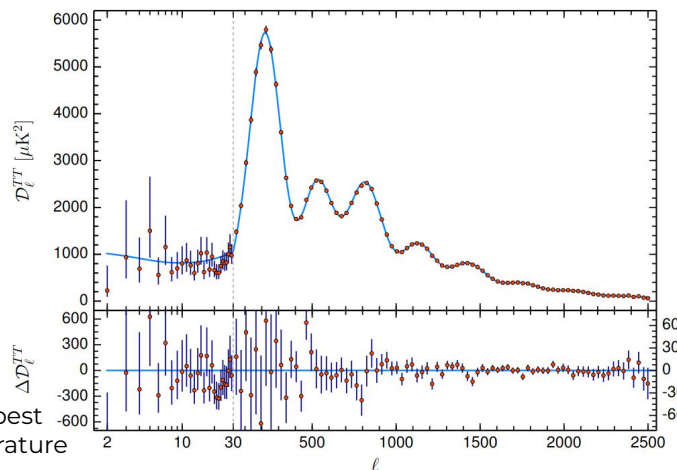
- **Brilliantly explains the evolution of the Universe** (CMB physics, formation of structures ...)

- **The model is favored** over alternative dark energy models **by most of observational surveys**

Λ CDM is great ...



DES Year 3
constraints in
the w_0w_a
plane.
Abbott+23

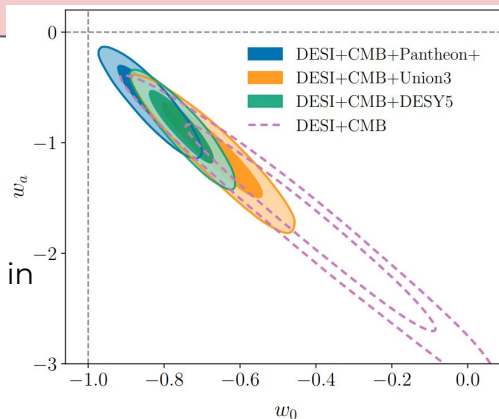


Planck 18 Λ CDM best
fit on CMB temperature
power spectrum
Aghanim+21

Failures of the Λ CDM model

... Λ CDM is not satisfying

- **The Hubble tension** = tension between early and late Universe probes on H_0
- **Recent deviations** observed from Λ CDM by DESI and DES-SN
- **Lack of theoretical interpretation** for the cosmological constant Λ (could be associated with the energy of vacuum but QFT calculations strongly disfavor it)



DESI DR2 constraints in the w_0w_a plane.
Abdul Karim+25

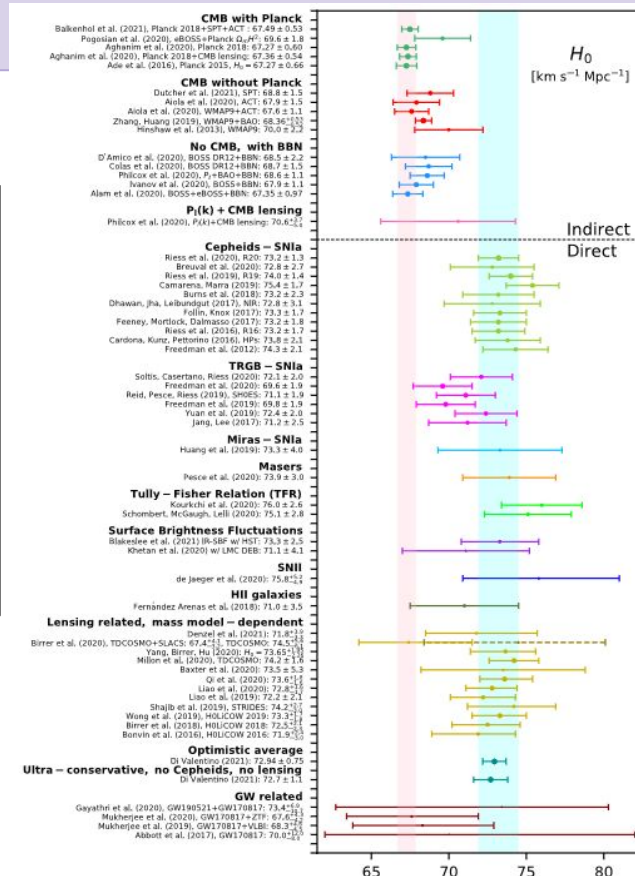


Illustration of the Hubble tension.
Di Valentino+21

wCDM models as alternative to Λ CDM

wCDM = simplest modification of Λ CDM (of the dark energy part)

Adding of a **scalar field** that is **minimally coupled** = does not depend on the curvature directly

Equivalent to postulate the existence of a new particle
(a spin-0 boson, like the Higgs)

This new component is able to produce an late-time accelerated expansion
(but the way the Universe expands and is accelerated differs from Λ CDM)

Reproduces the successes of Λ CDM while giving a nature to dark energy

One free parameter $\longrightarrow$ state parameter of the scalar field w $p = w\rho c^2$

pressure

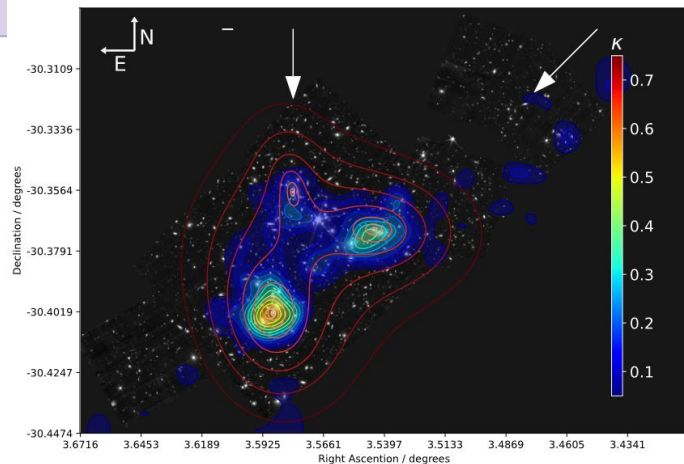
density

Galaxy clusters

The most massive bound structures of the Universe ($10^{14} - 2 \times 10^{15} M_{\odot}$).

Observed through:

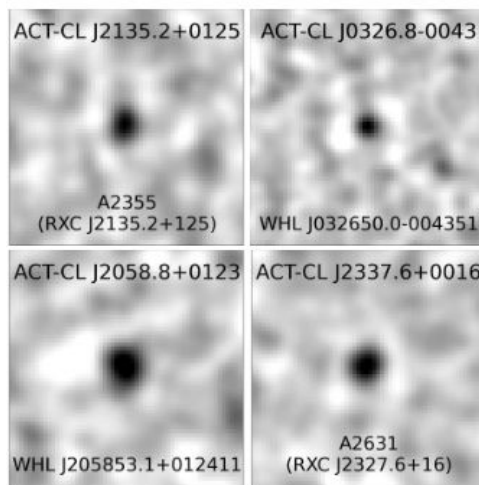
- Optical/IR light
- X-ray emissions
- Radio signal
(Sunyaev-Zeldovich effect)
- Gravitational lensing
(weak lensing)



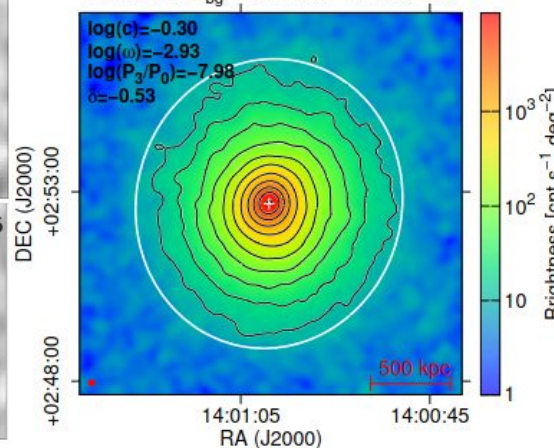
Weak lensing convergence map of A2744.

Harvey+24

XMM-Newton image of A1835. **Yuan+22**



A1835 ($z=0.2532$): XMM-Newton image
Contours: $\langle S_{bg} \rangle + 5 \times 2^n \sigma$, $n = 0, 1, 2, 3, \dots$



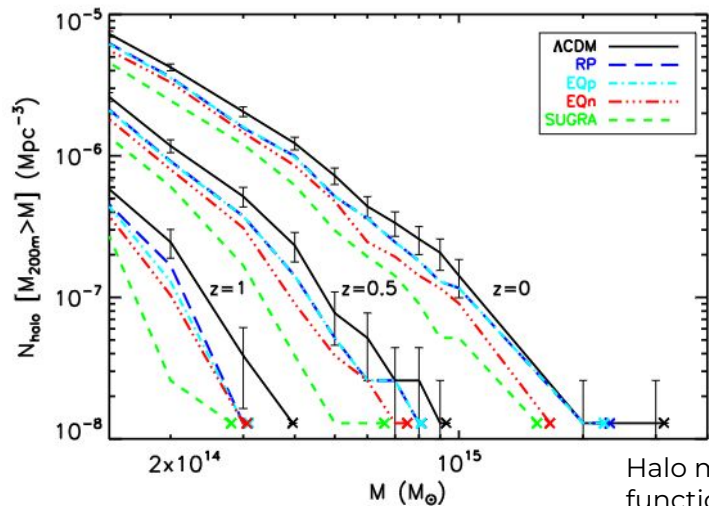
ACT-CL SZ of 4 galaxy clusters. **Hasselfield+13**

Galaxy clusters

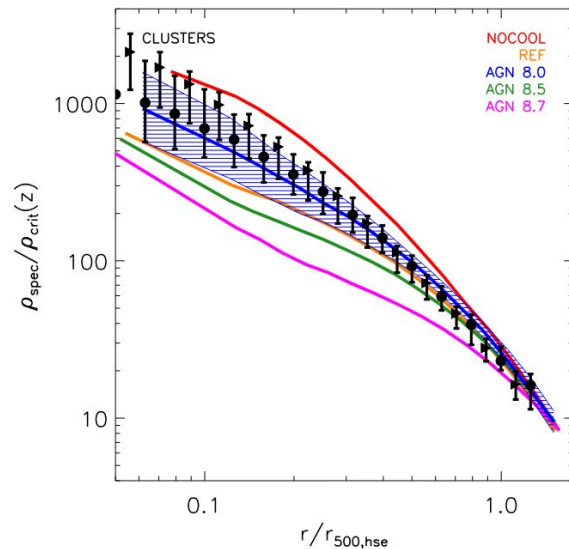
- Galaxy clusters contains the imprint of the dark energy model they evolved in eg. Dolag+04, Kuhlen+04, De Boni+10,+13.

- Also sensitive to baryonic physics, especially AGN feedback eg. Teyssier+10, Le Brun+14, Hahn+15,+23.

Important to study realistic population of galaxy clusters in non Λ CDM scenarios to give unbiased predictions for cosmological inference from LSS surveys (not done yet)



Halo mass functions for different dark energy models
De Boni+10



Stacked density profiles for different AGN models
Le Brun+14

The ADELINe simulations Tornatore+26 in prep

Purpose: Study the effect of w CDM dark energy in the internal properties of massive galaxy clusters through zoom-in simulations

9 massive systems ($> 1e15 M_{\text{sun}}$) re-simulated from a DMO 1 Gpc box

- 2 w CDM cosmologies: $w = -0.8$ $w = -1.2$
- 1 Λ CDM cosmology: $w = -1.0$

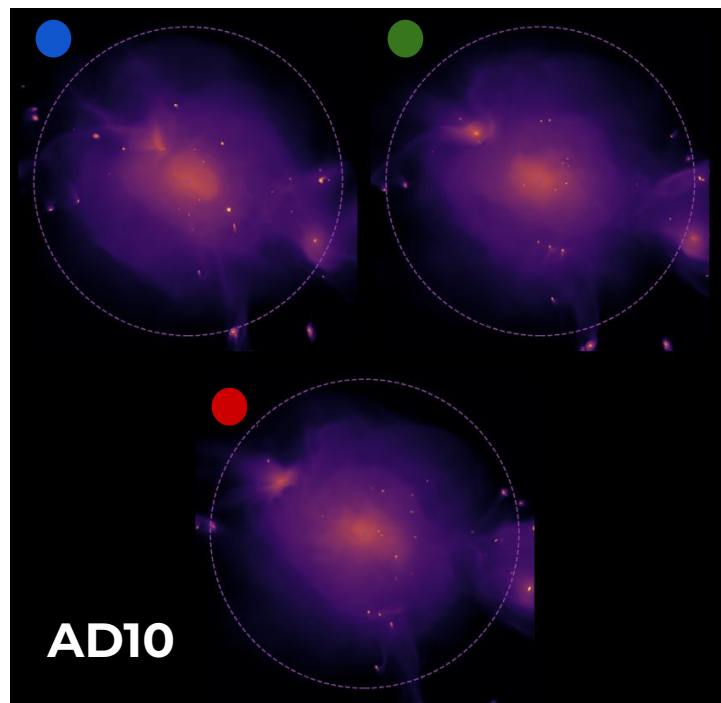
1kpc resolution / $1.8e8 M_{\text{sun}}$

RAMSES code (Teyssier+02)

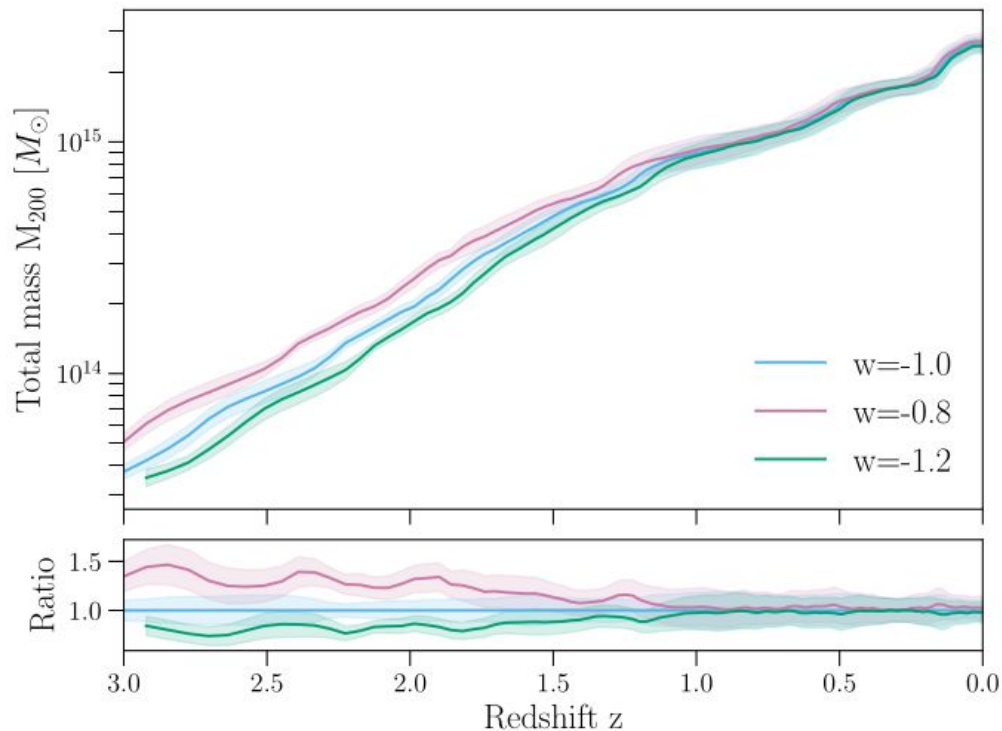
Baryonic physics from HorizonAGN (Dubois+14)

$\sim 240\,000$ cpuh per run

- 30% of allocation used



Clusters masses evolution with redshift: total mass



Average evolution of M_{200} between $z=3$ and $z=0$

Significant differences in the range $z=[3.0-1.0]$

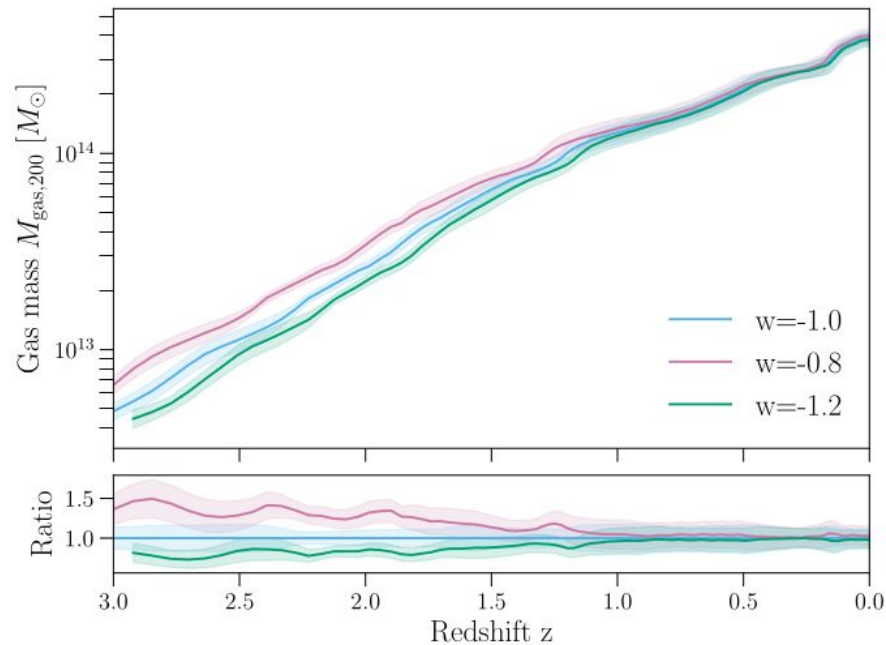
Effect of the differences in the initial densities. Higher initial fluctuations in the **quintessence** and the **Λ CDM** models than in the **phantom** one



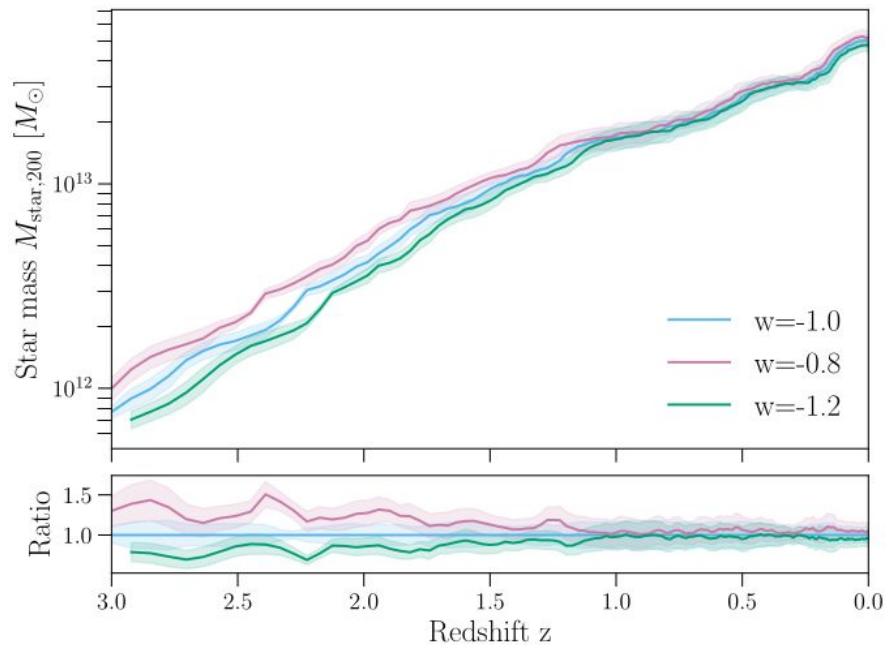
Differences are narrowing in the range $z=[1.0-0.0]$

Effect of dark energy that slows down mass accretion more efficiently in the **quintessence** and the **Λ CDM** models than in the **phantom** one

Clusters masses evolution with redshift: star and gas masses



Average evolution of $M_{\text{gas},200}$ between $z=3$ and $z=0$

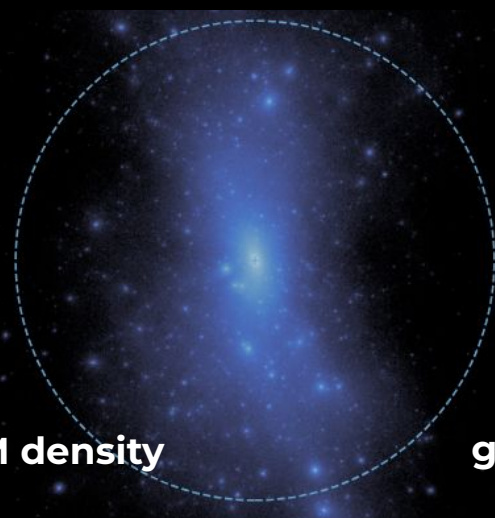


Average evolution of $M_{\text{star},200}$ between $z=3$ and $z=0$

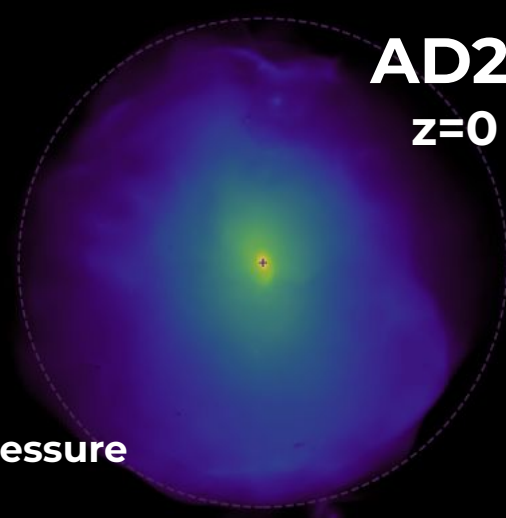
- We don't spot any early time sur-amplification in the gas/star mass with respect to the total mass

**Thanks for your
attention!**

DM density

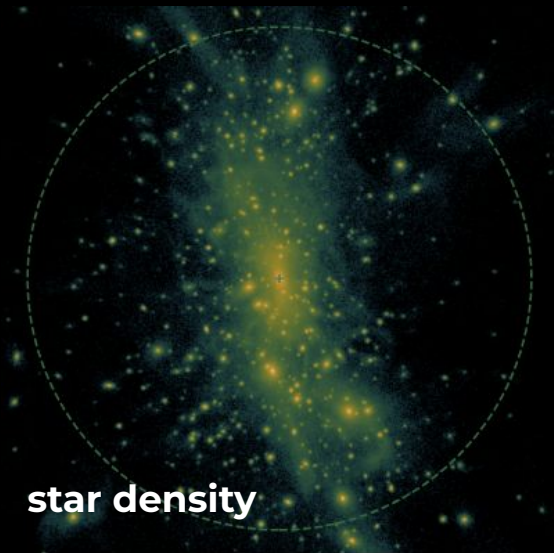


gas pressure

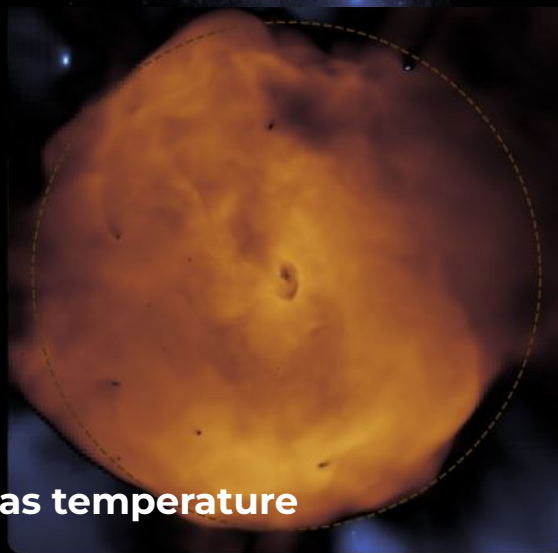


AD24
z=0

star density



gas temperature



gas density

