The Jubilee Simulation

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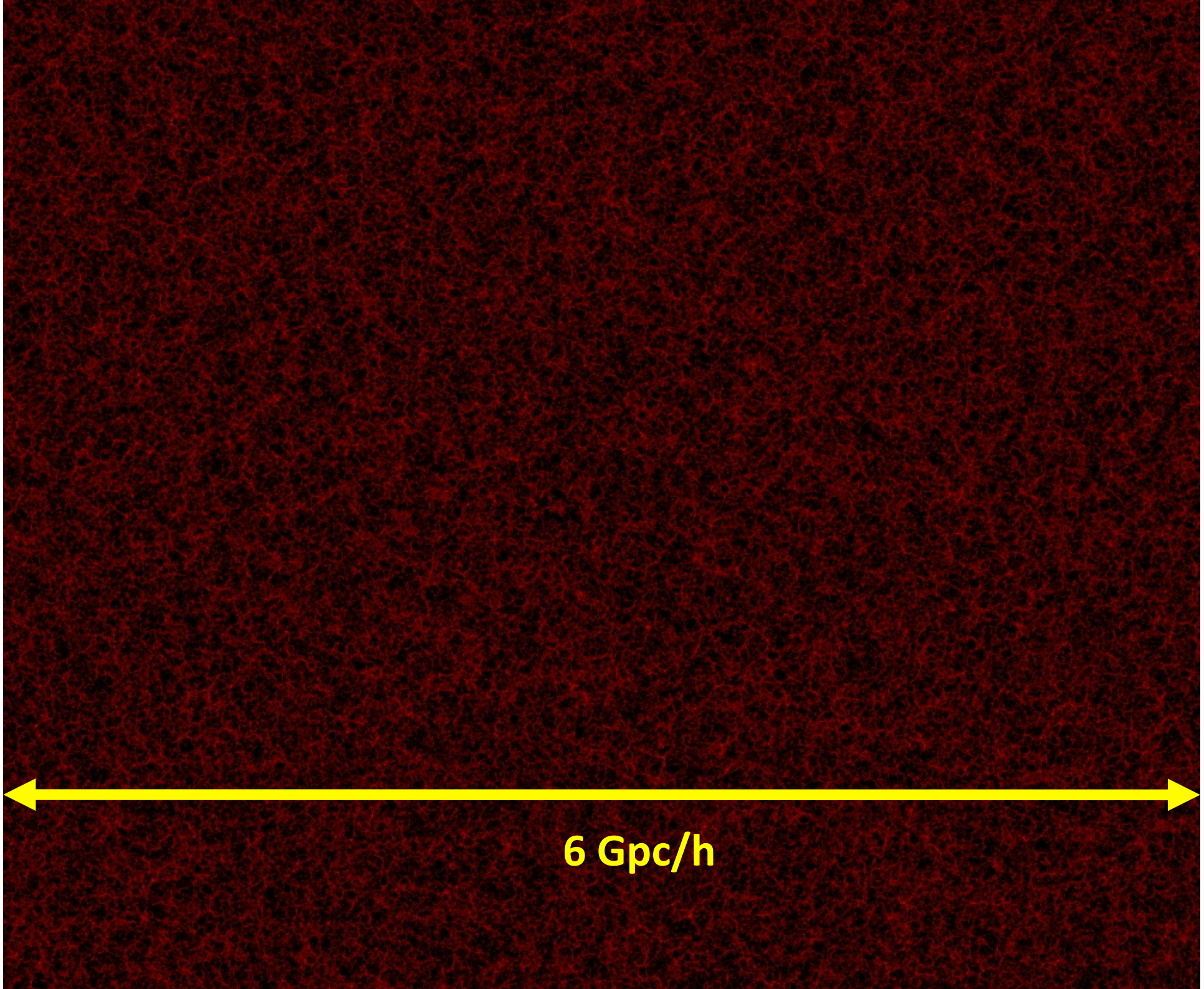
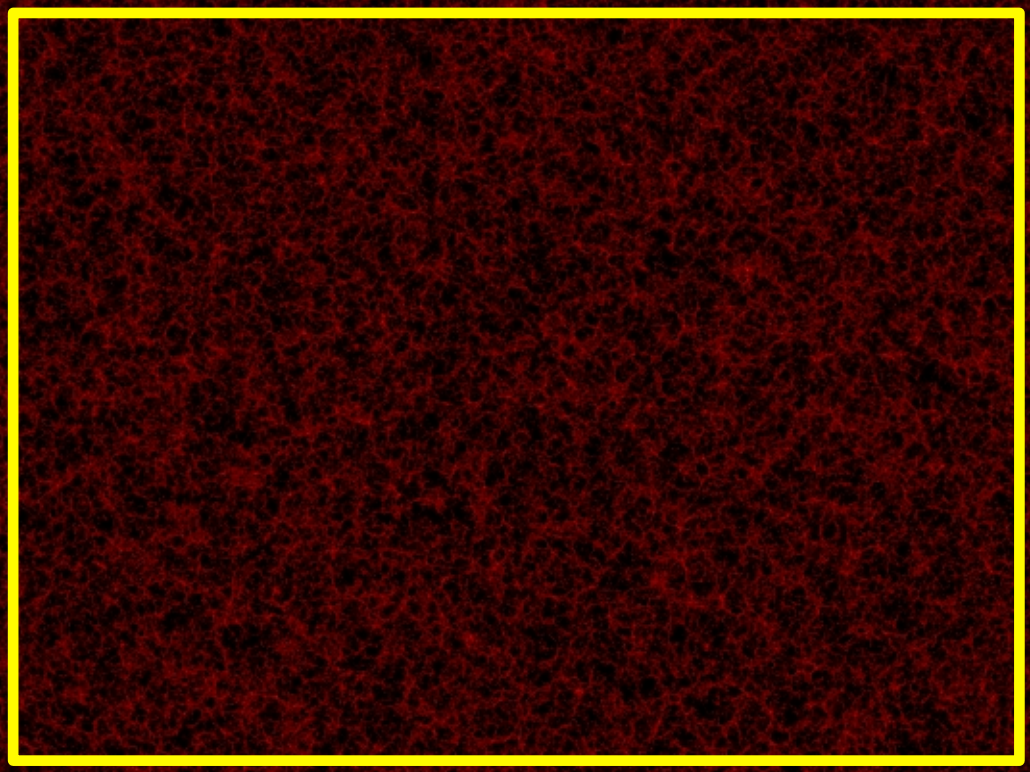
The JUropa huBbLE volumE (JUBILEE) Project

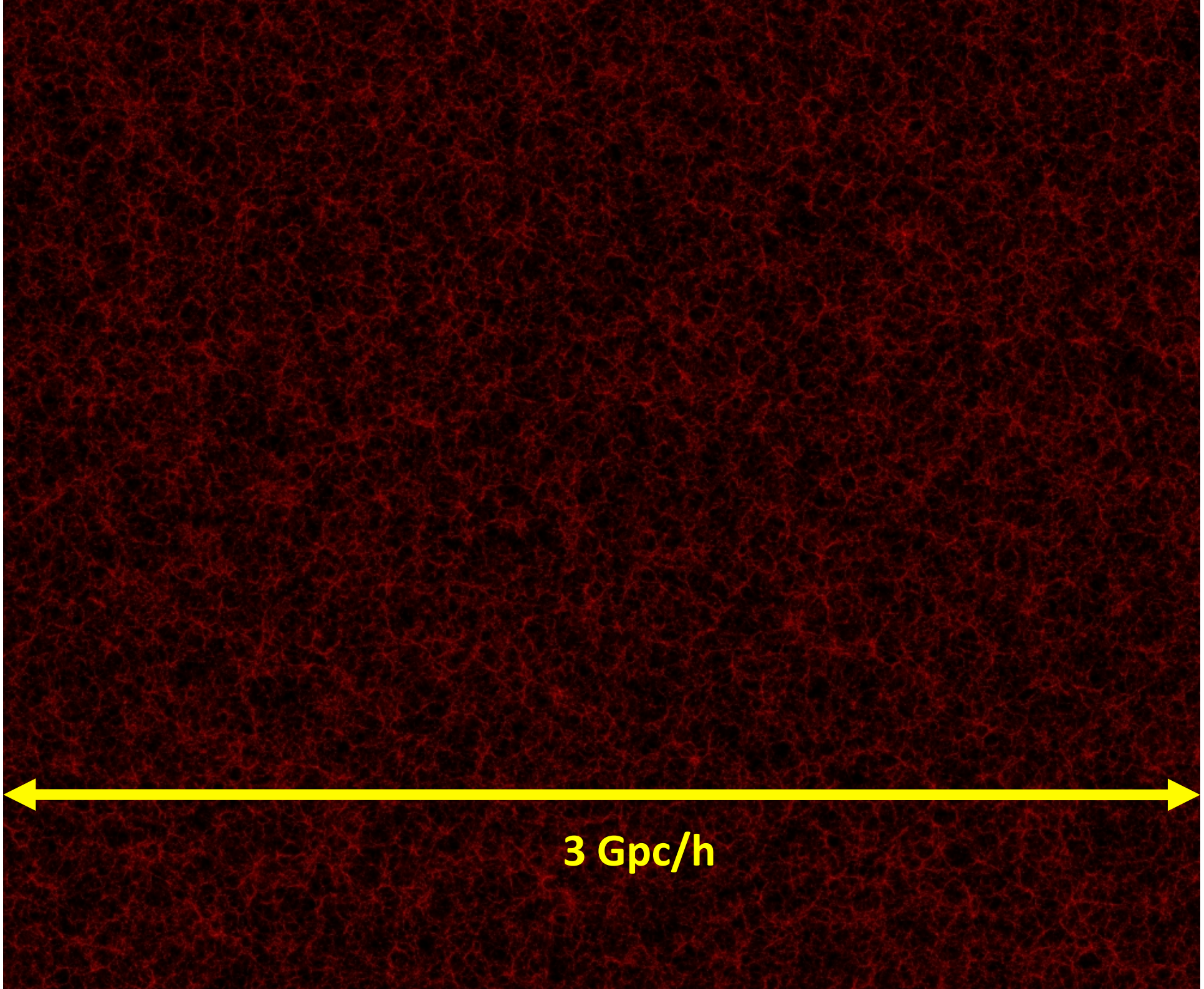
- Collaboration: Ilian Iliev (Sussex), Gustavo Yepes (UAM), Alexander Knebe (UAM), Stefan Gottloeber (AIP), Jose Maria Diego (UniCan), E. Martínez González (IFCA)
- Simulation run late 2011, taking ~1.5 million computing hours, on Juropa at the Jülich Supercomputing Centre (JSC), Germany. Using 8000 cores.
- 6 Gpc/h box size, 6000^3 particles (216 Billion), Particle Mass: 7.49×10^{10} /h M_{sun}, resolution down to the smoothing length of 50kpc/h
- 30 output slices stored of particle data (halo catalogues stored for 105 slices) – totaling ~150 TB of data
- WMAP 5 cosmology (Ω_M= 0.27; Ω_Λ= 0.73; h = 0.7; σ_8 =0.8; n=0.96; Ω_{baryon}= 0.044)
- Code used was CubeP^{3}M, a massively parallel, collisionless dark matter N-body code
- jubilee.ft.uam.es/simulations

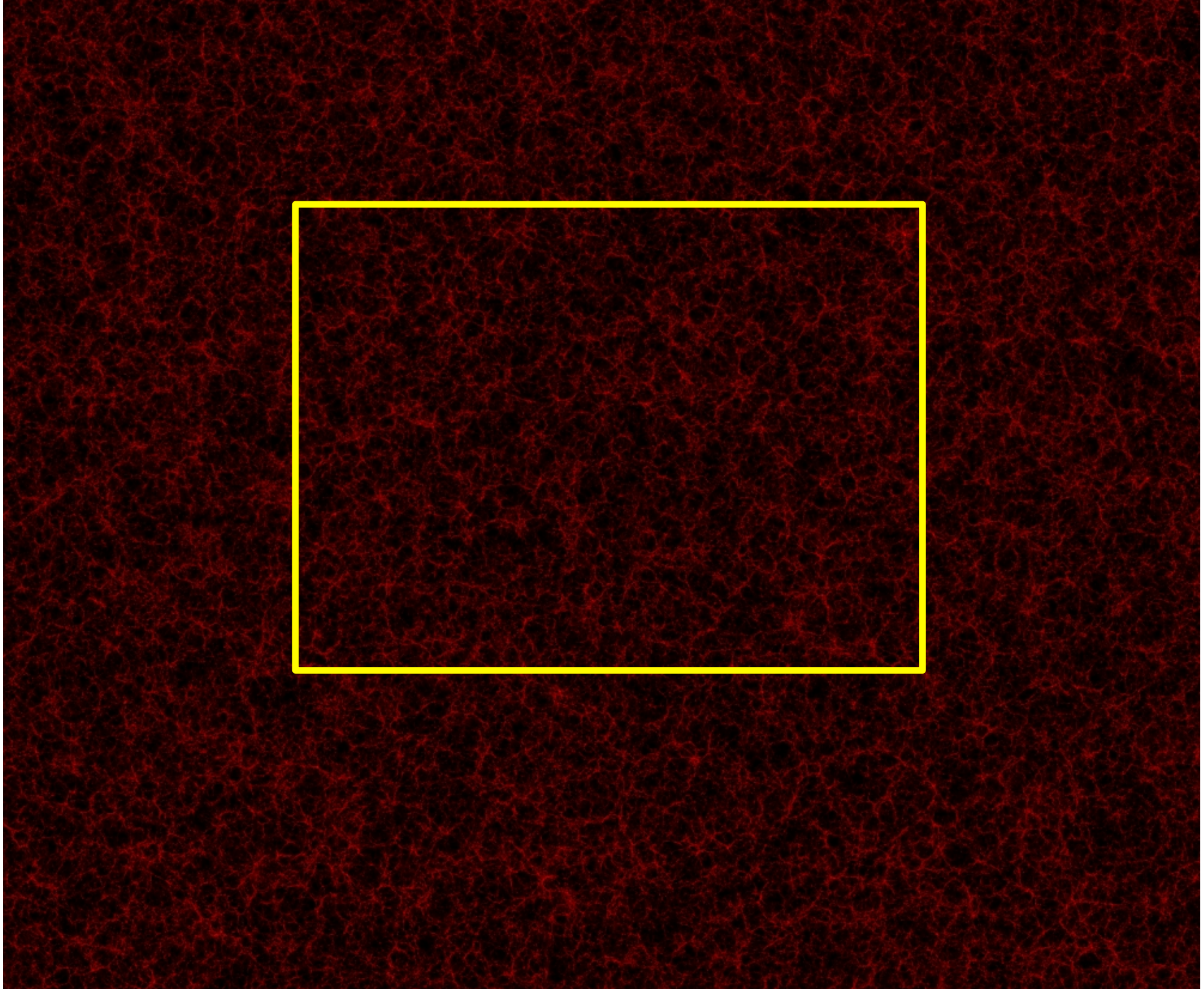
Jubilee Science Goals

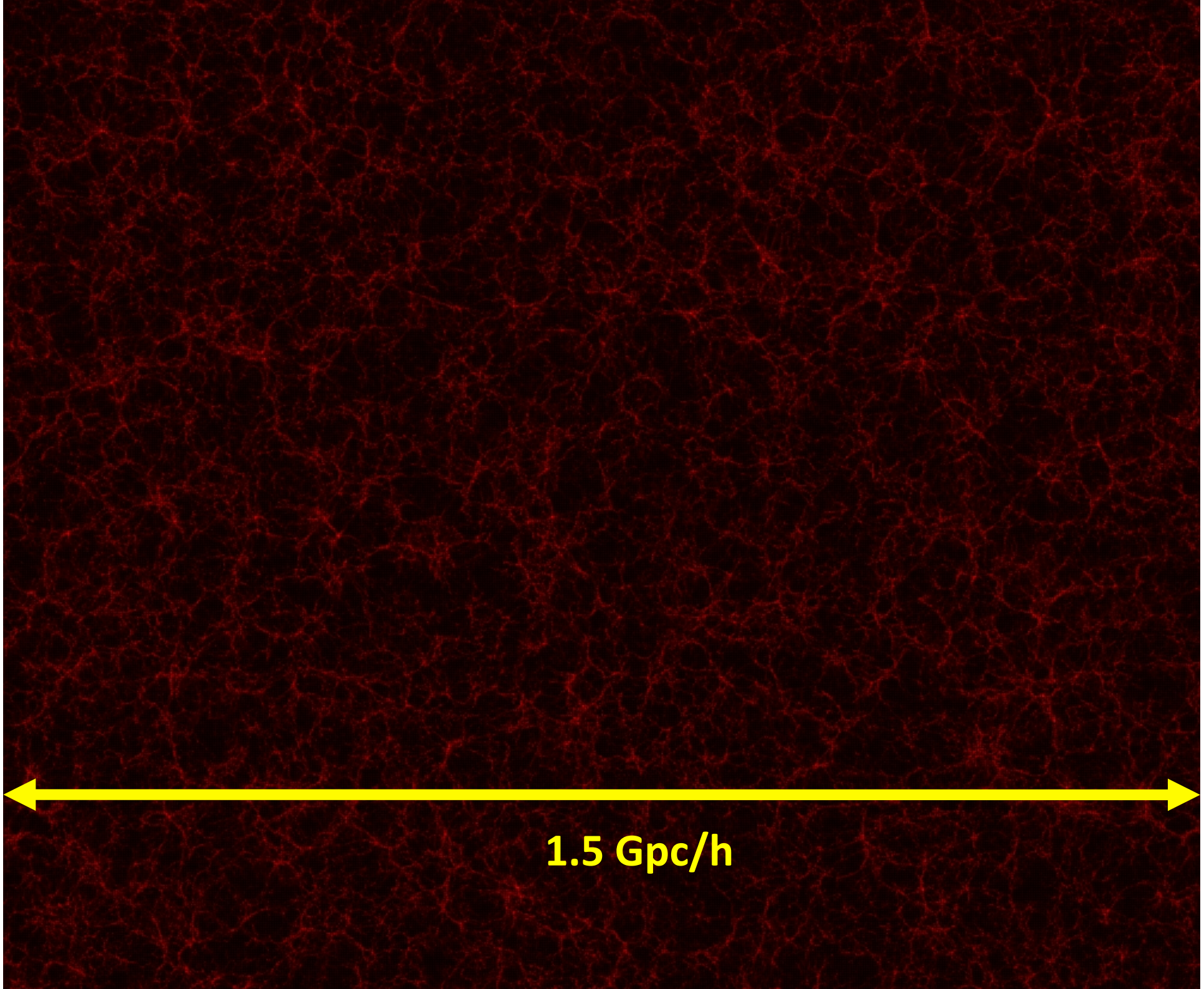
- All-sky map of the Integrated Sachs-Wolfe effect (or ISW)
- Catalogs of luminous red galaxies (or LRG), radio and IR galaxies
- All sky maps of the Sunyaev-Zel'dovich (or SZ) effect
- All sky maps of lensing effects

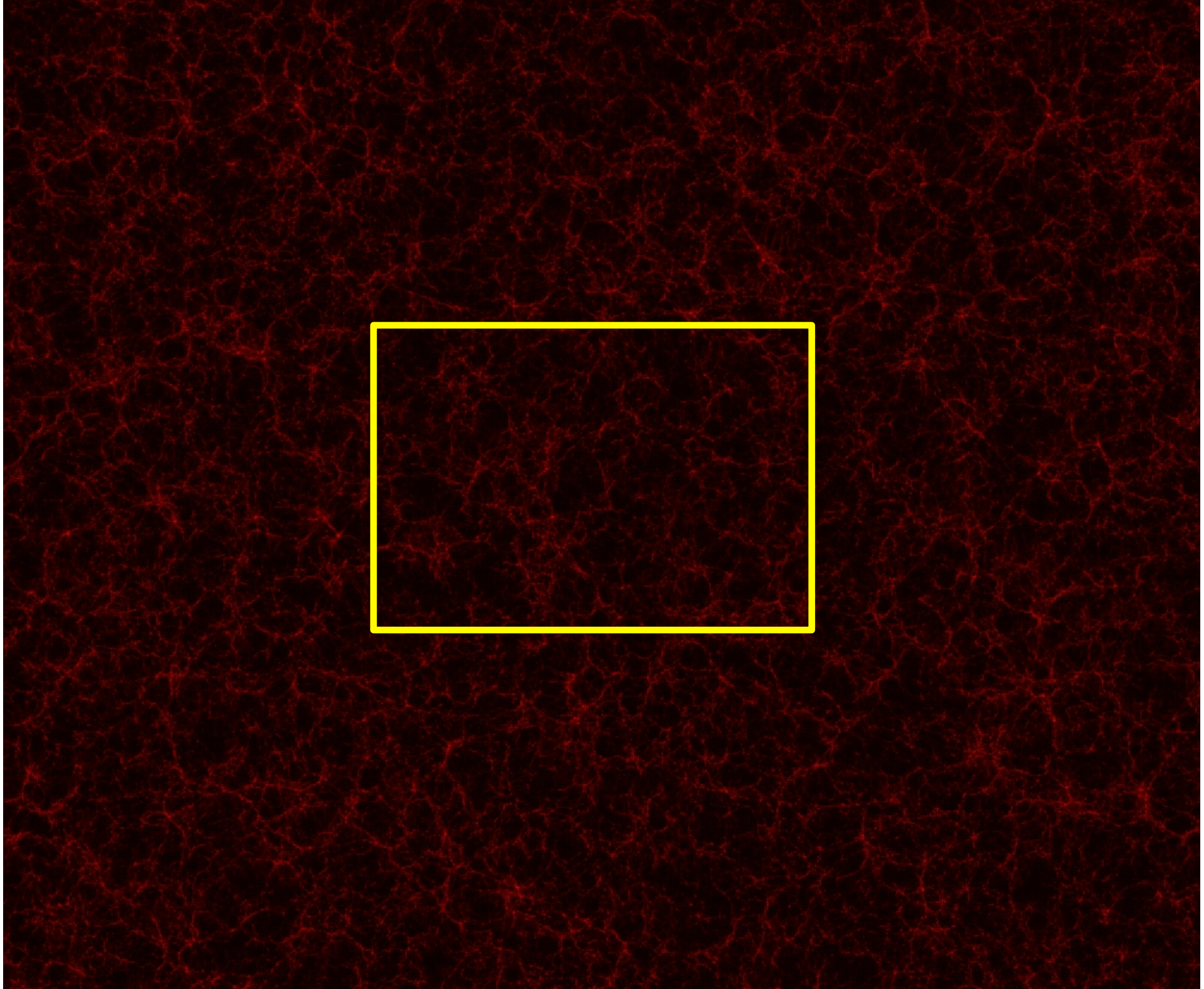

6 Gpc/h

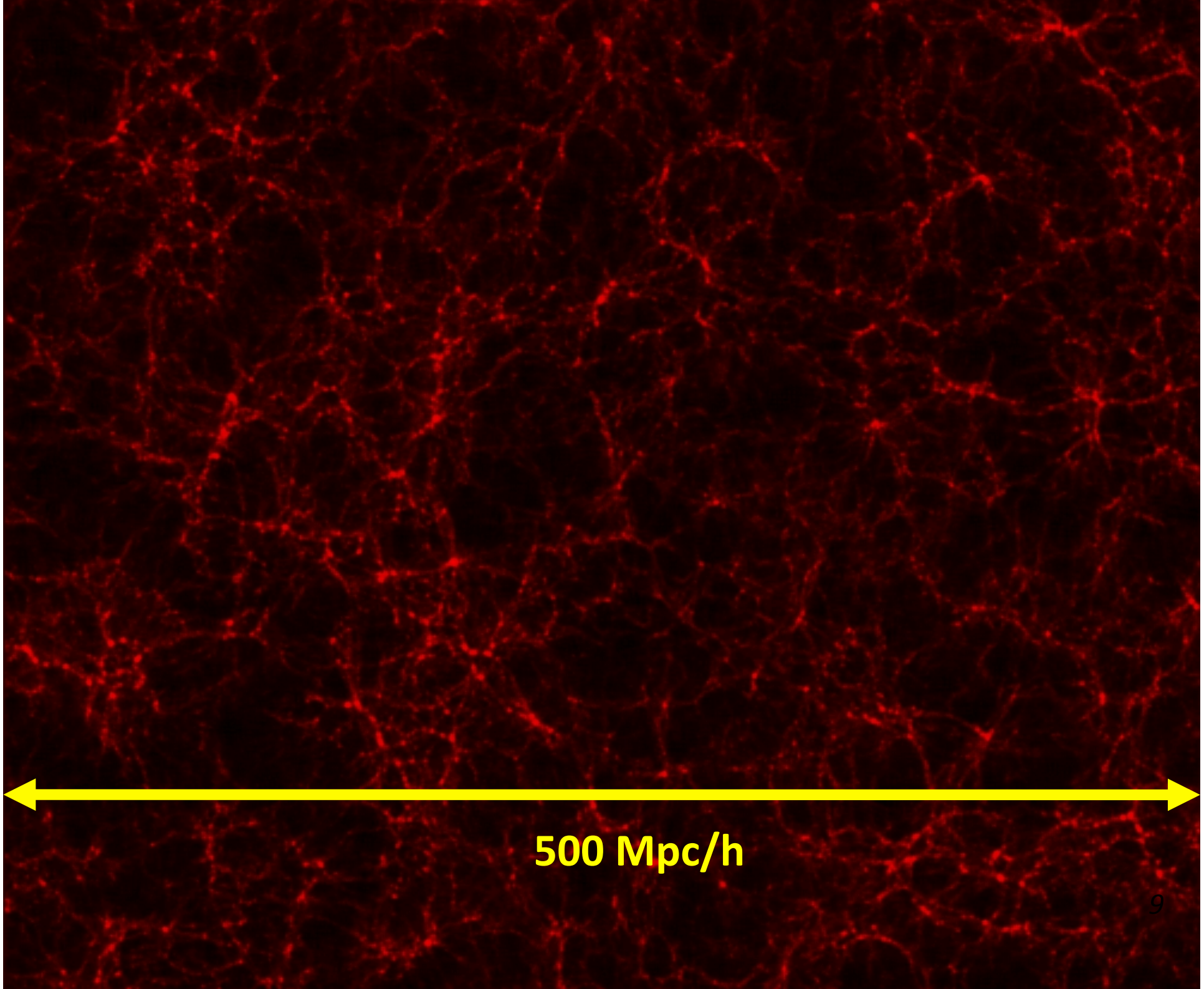



3 Gpc/h

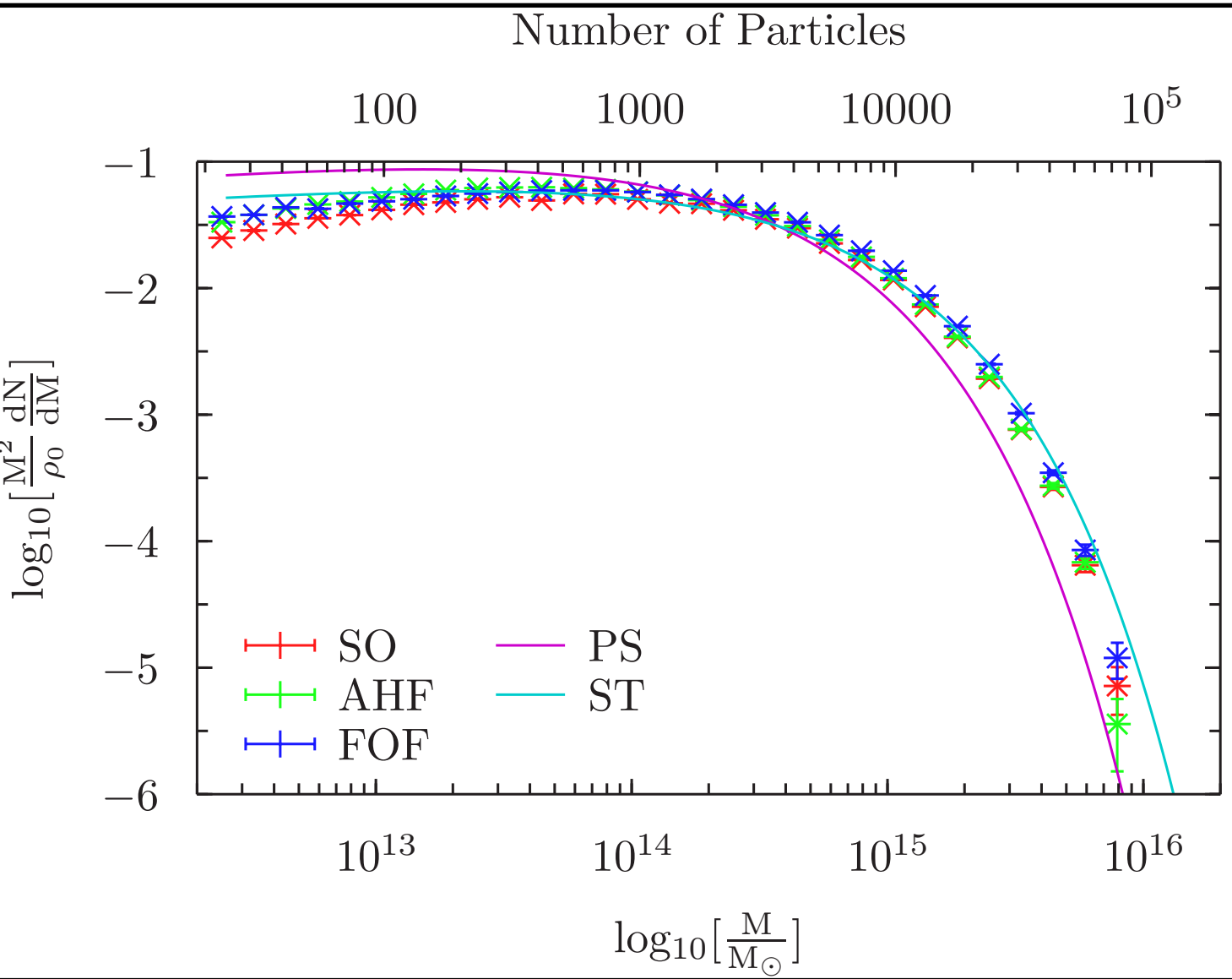



1.5 Gpc/h

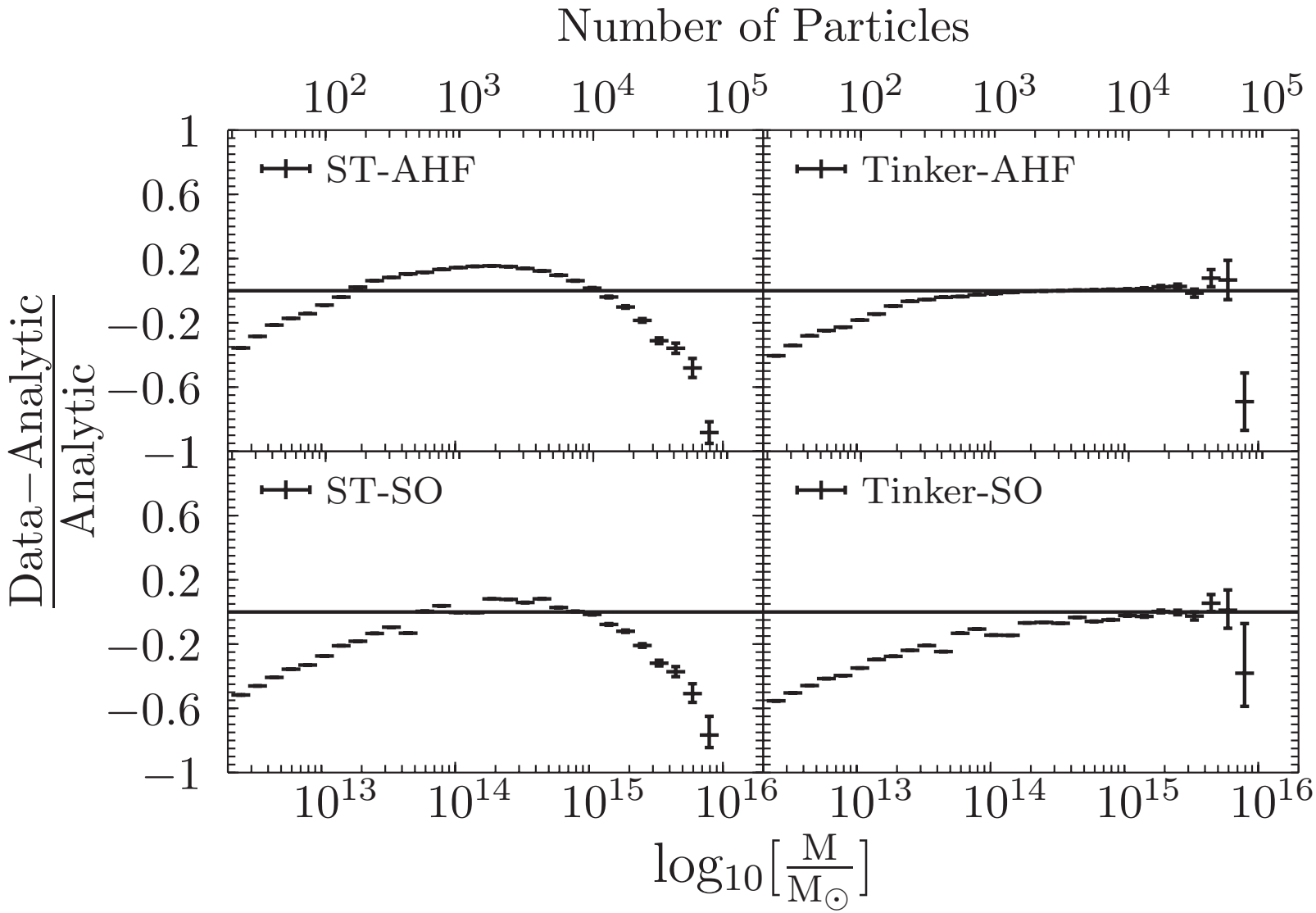



500 Mpc/h

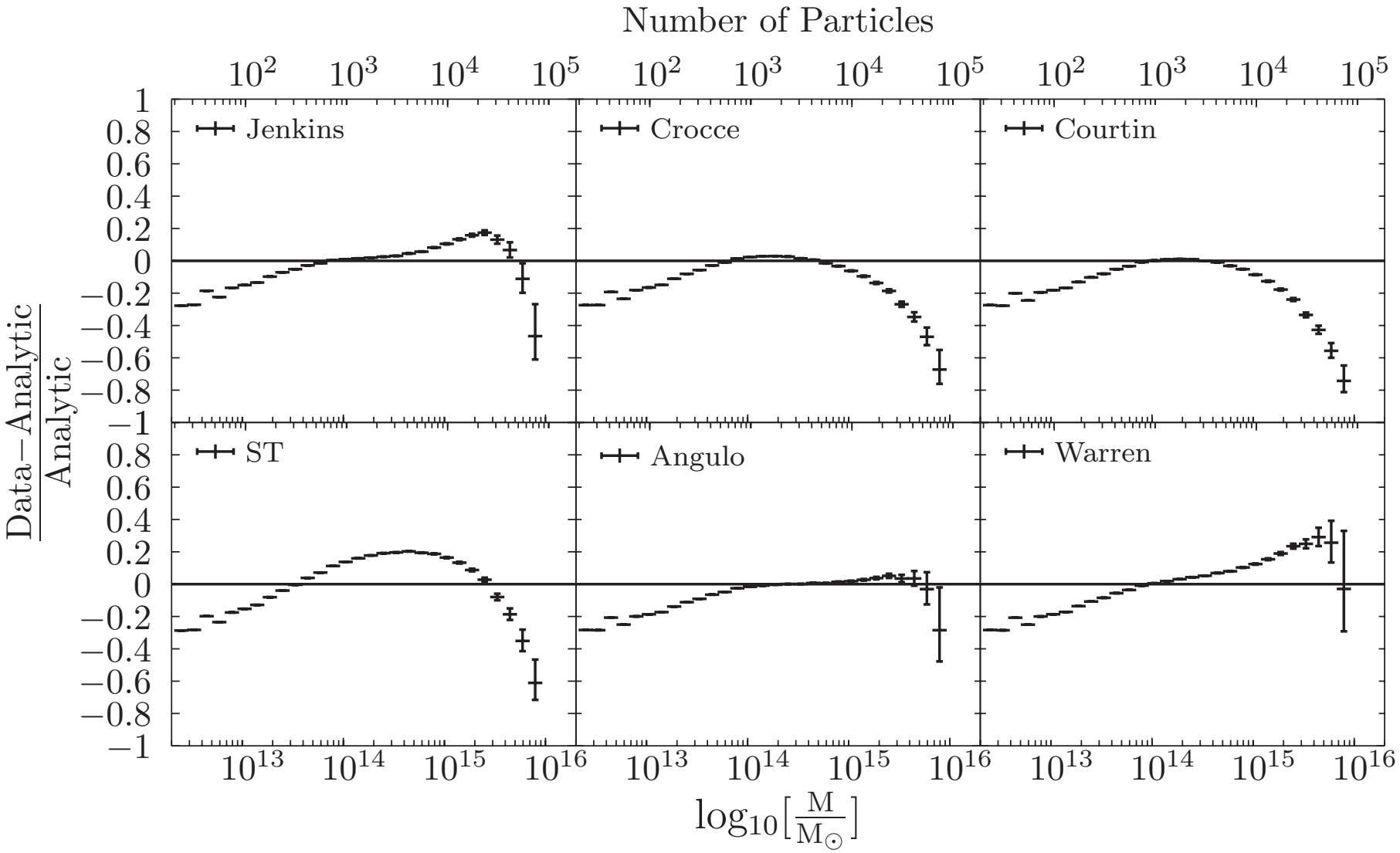
The Jubilee Mass Function



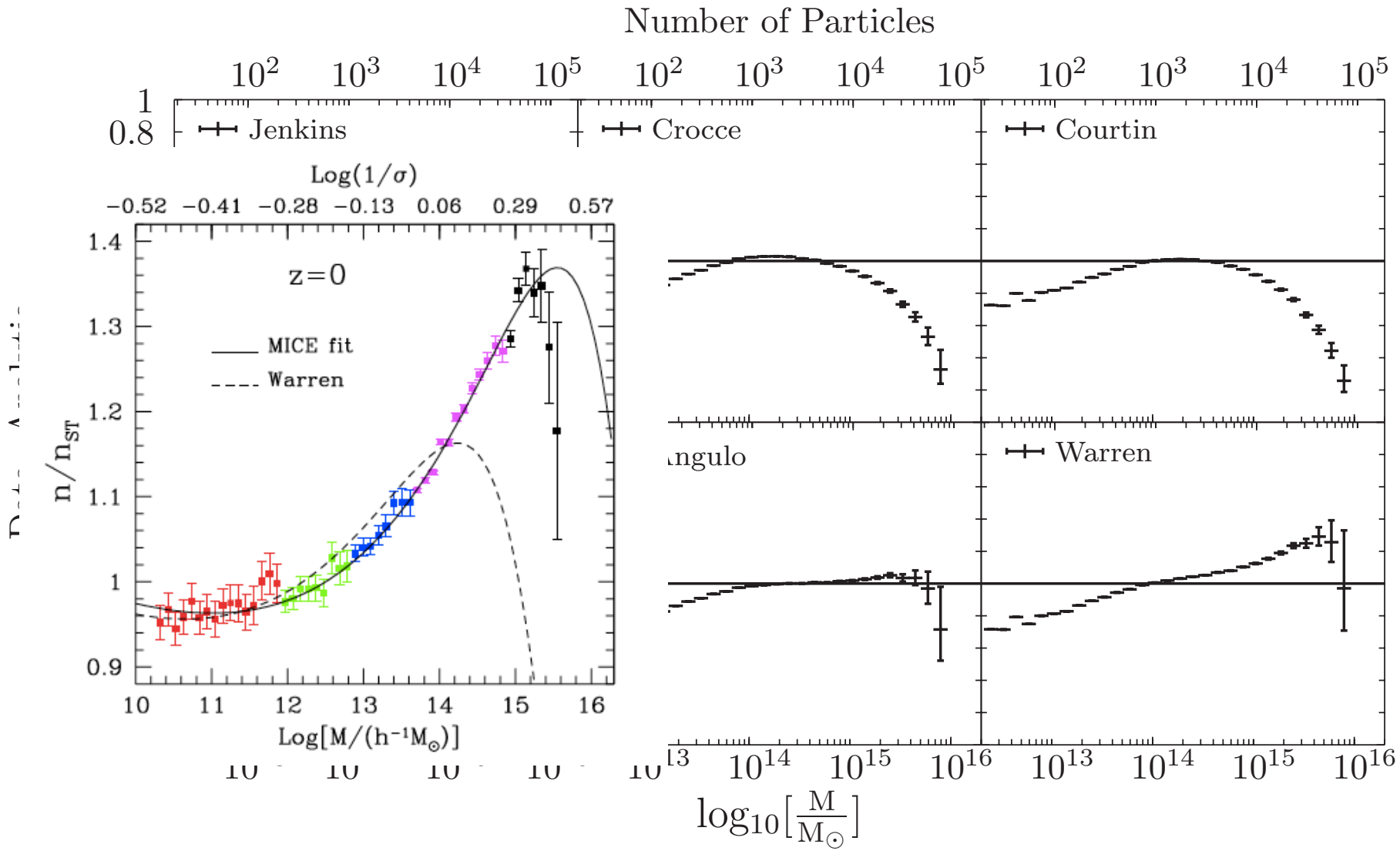
SO and AHF Residuals z = 0



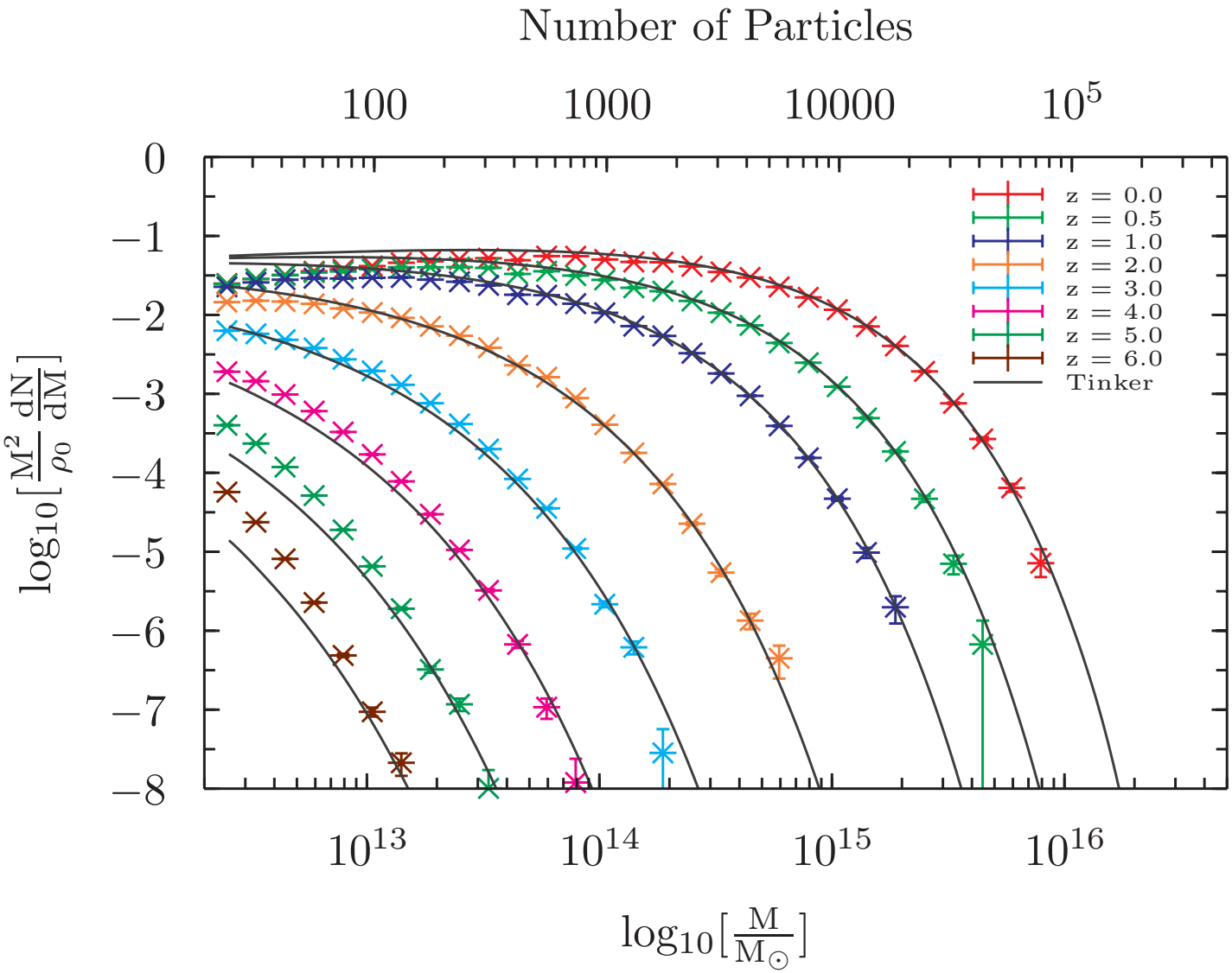
FOF Residuals z = 0



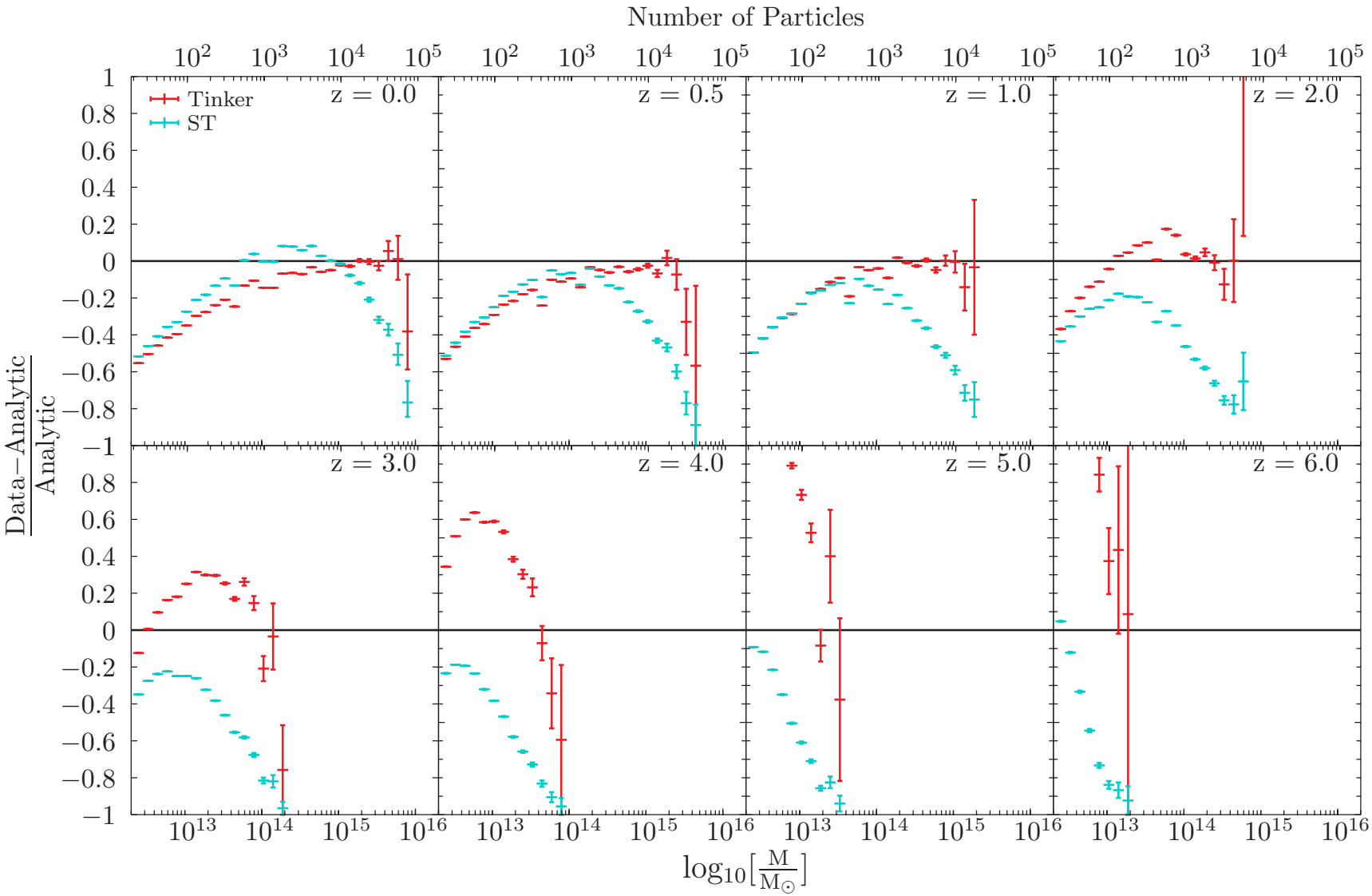
FOF Residuals z = 0



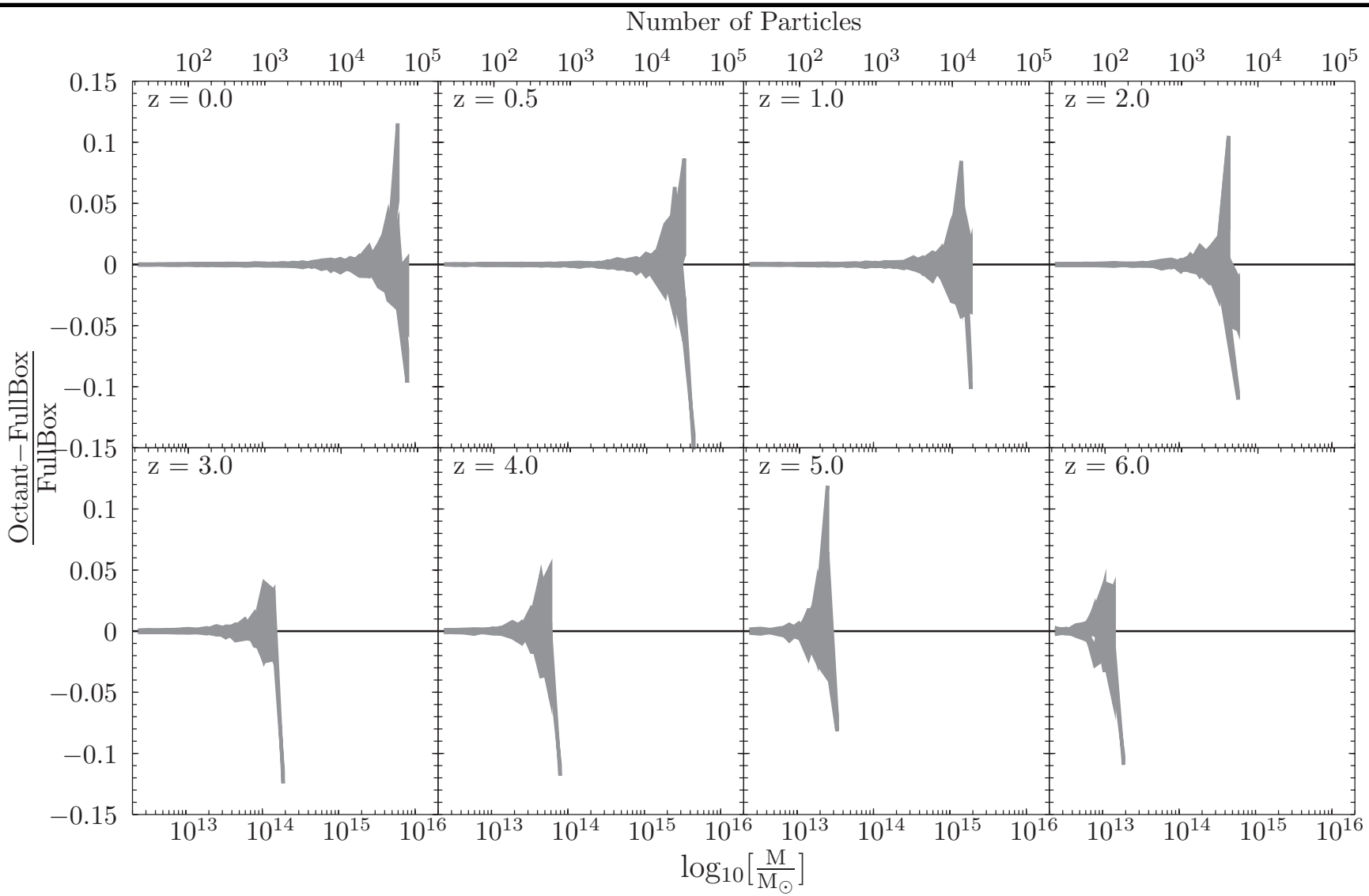
Redshift Evolution



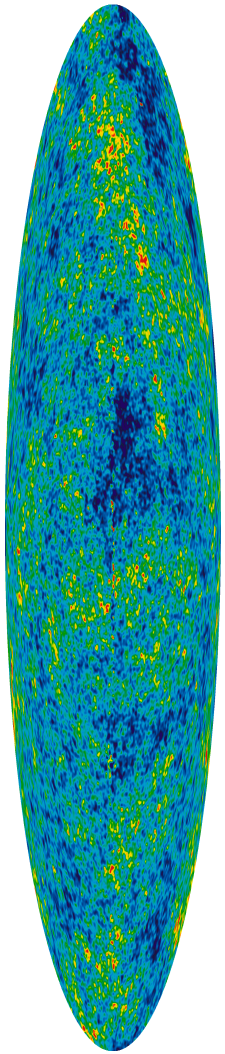
Redshift Evolution



Cosmic Variance – Mass Function



Simulating The ISW Effect



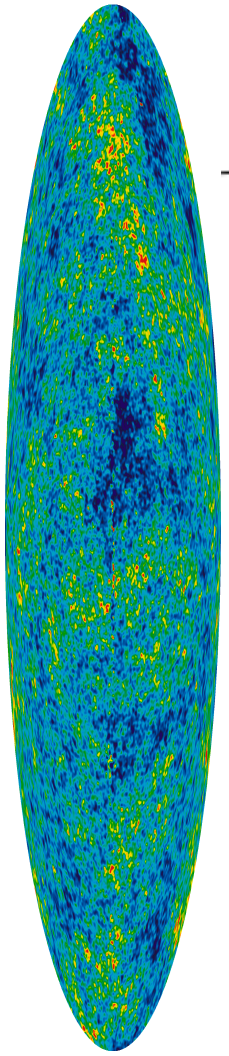
T (z = CMB)

T (z = 0)

EdS Universe

Φ

Simulating The ISW Effect



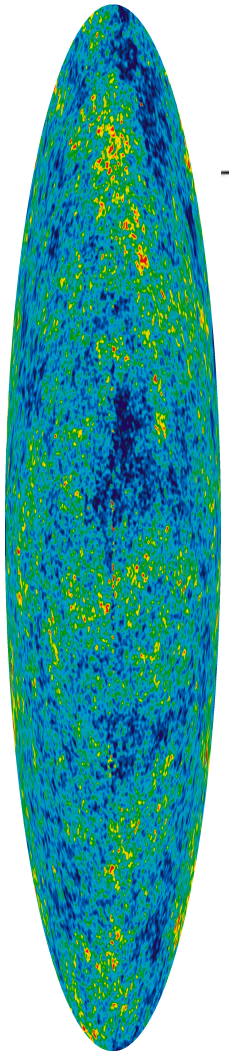
T (z = CMB)

ΛCDM Universe

Φ

T + ΔT (z = 0)

Simulating The ISW Effect



T (z = CMB)

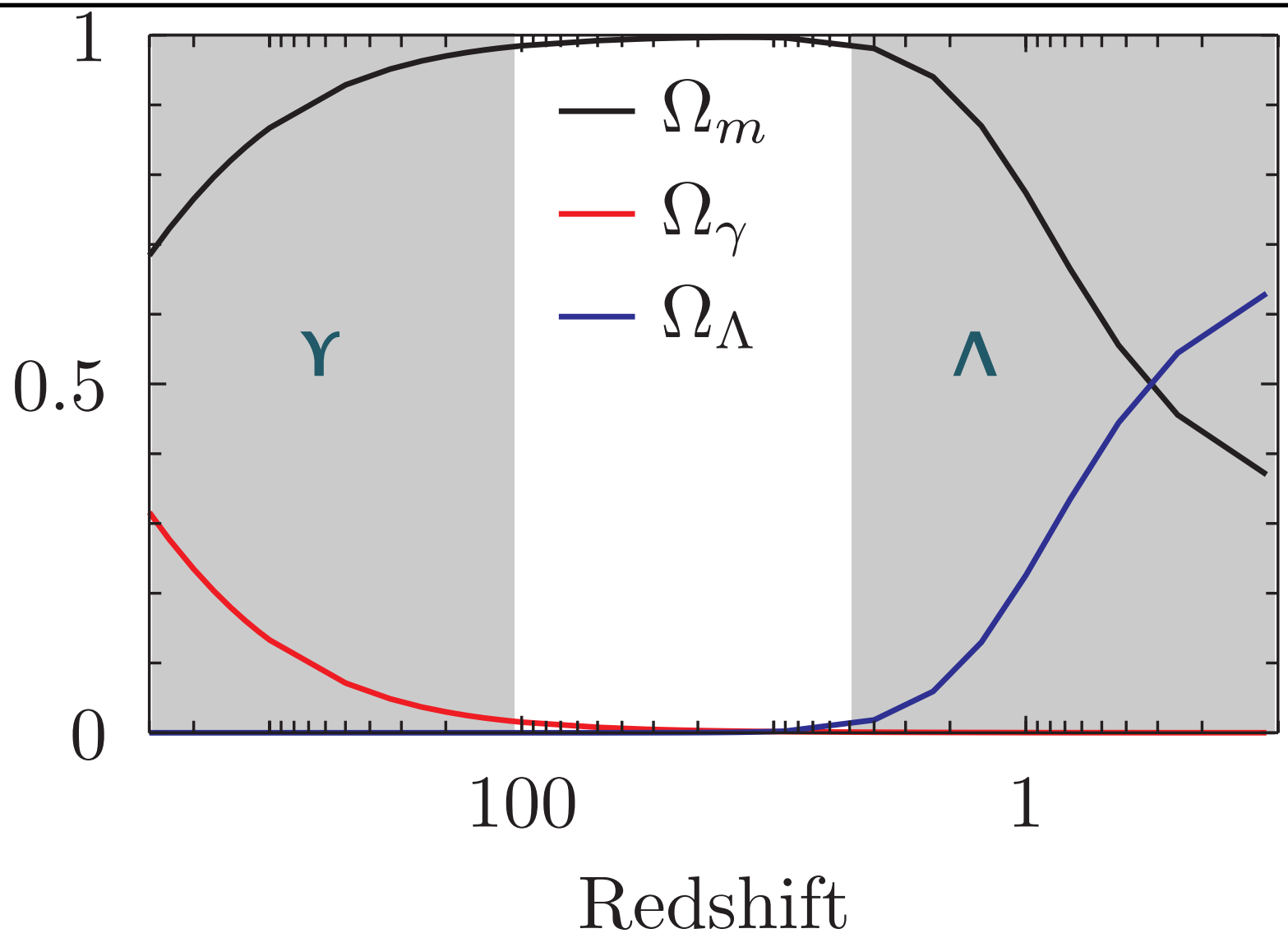
T + ΔT (z = 0)

ΛCDM Universe

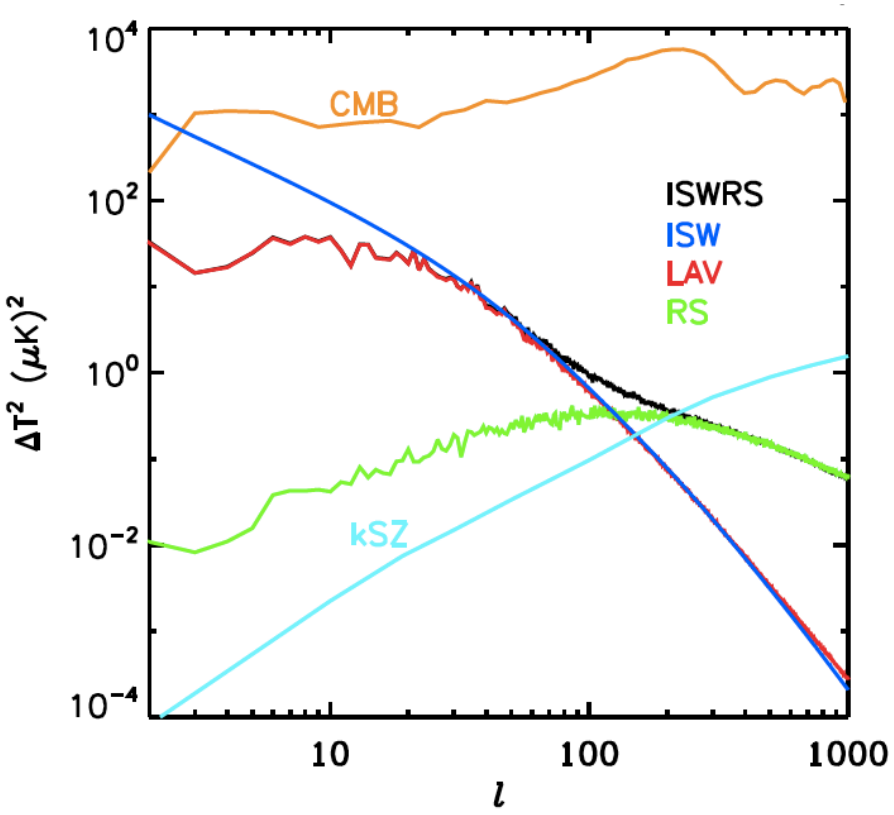
Φ

$$\Delta T(\hat{n}) = \frac{2}{c^2}\bar{T}_0 \int_{t_L}^{t_0} \dot{\Phi}(t,\hat{n})\, dt \quad \longleftrightarrow \quad \Delta T(\hat{n}) = \frac{2}{c^3}\bar{T}_0 \int_{0}^{r_L} \dot{\Phi}(r,\hat{n})\, a\, dr$$

When?



Where?



Cai et al. 2010

- Need a large volume to observe the effect as it occurs most strongly for large-scale perturbation modes in the density field (100s of Mpcs)
- For Jubilee we need to resolve down to the scale of Luminous Red Galaxies (LRGs) (10^{13} $M_\odot$ halos) to cross correlate with the ISW signal
- Need many snapshots to ensure integral is accurate (Jubilee has 30 between z = 0 and 6).

Potential Calculation

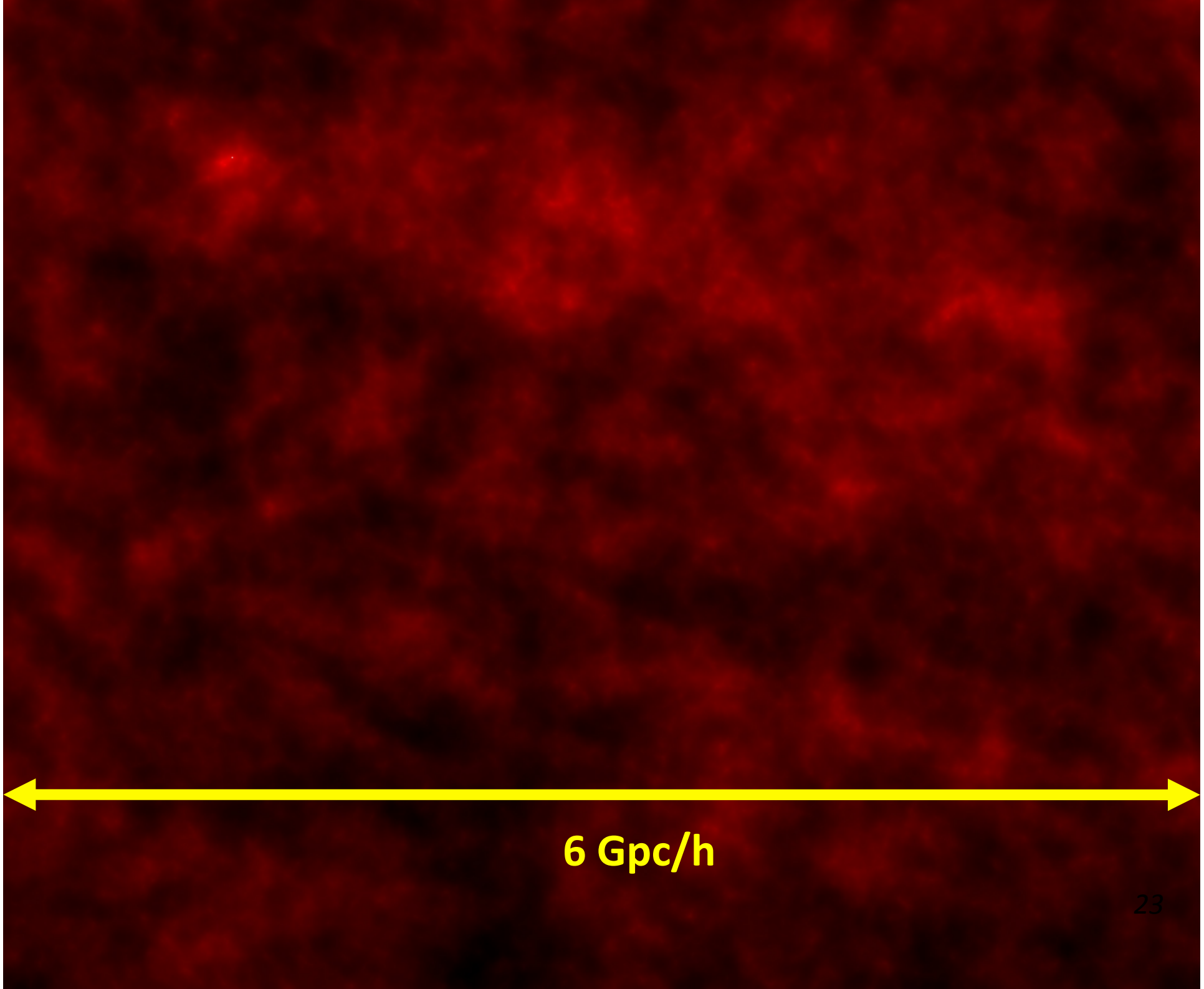
- We calculate the potential from the density:
  - Smooth the density field (CIC, 6000^3 grid)
  - Calculate the potential from the density using Poisson's equation:

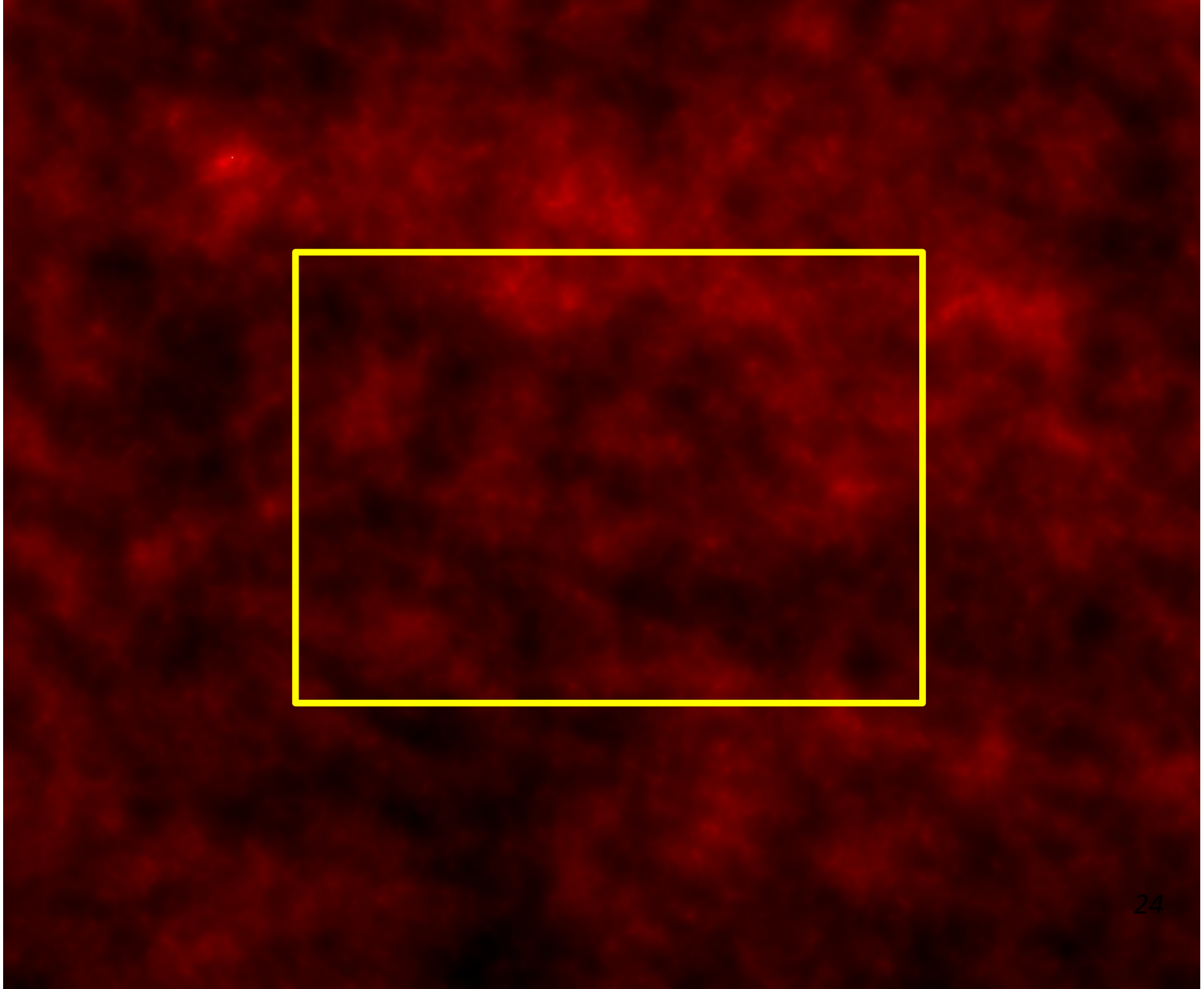
$$\nabla^2 \Phi(\vec{x}, t) = 4\pi G \bar{\rho}(t) a^2 \delta(\vec{x}, t)$$

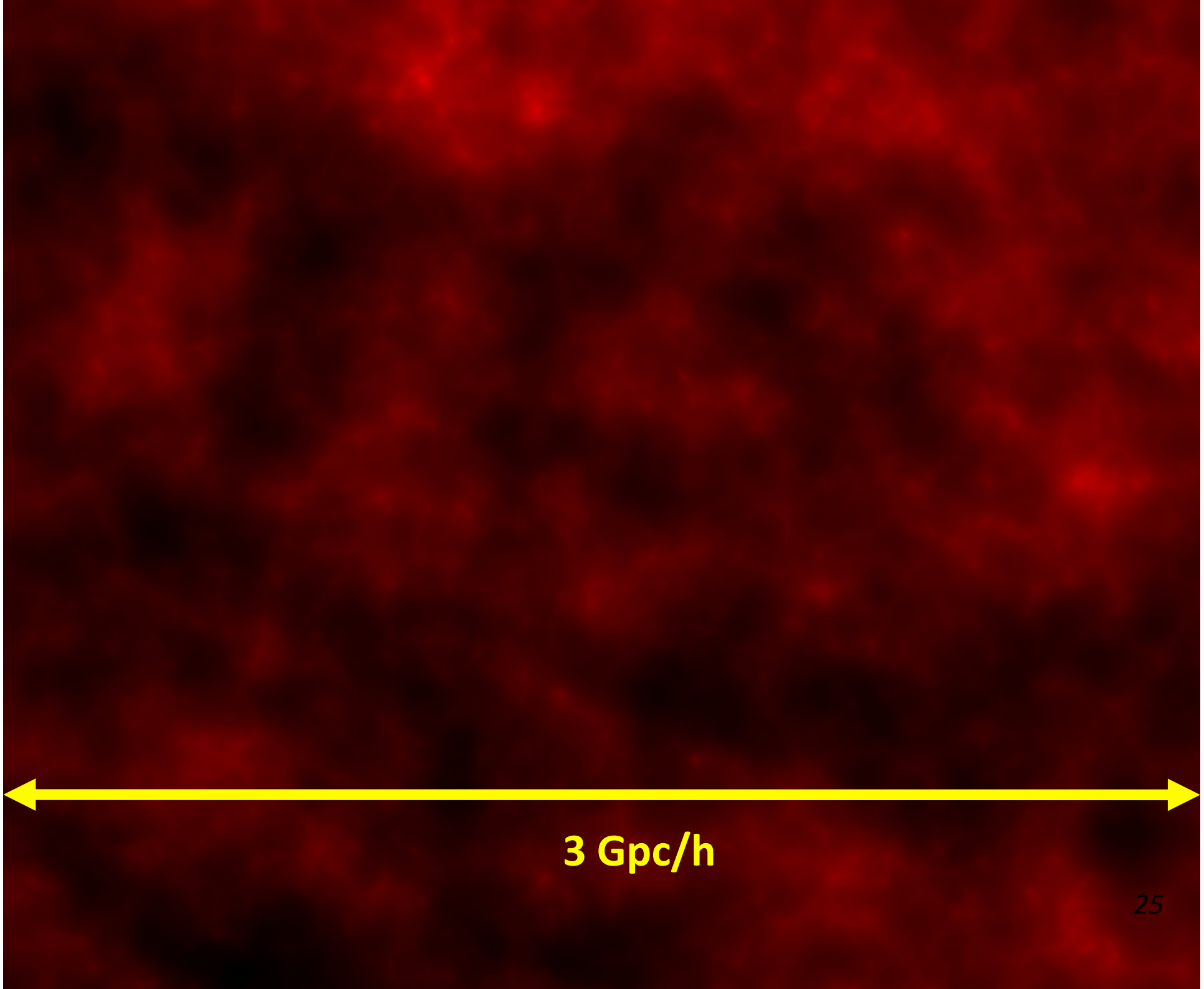
  - And the Multiple Fourier Transform (MFT) method (Hockney and Eastwood)

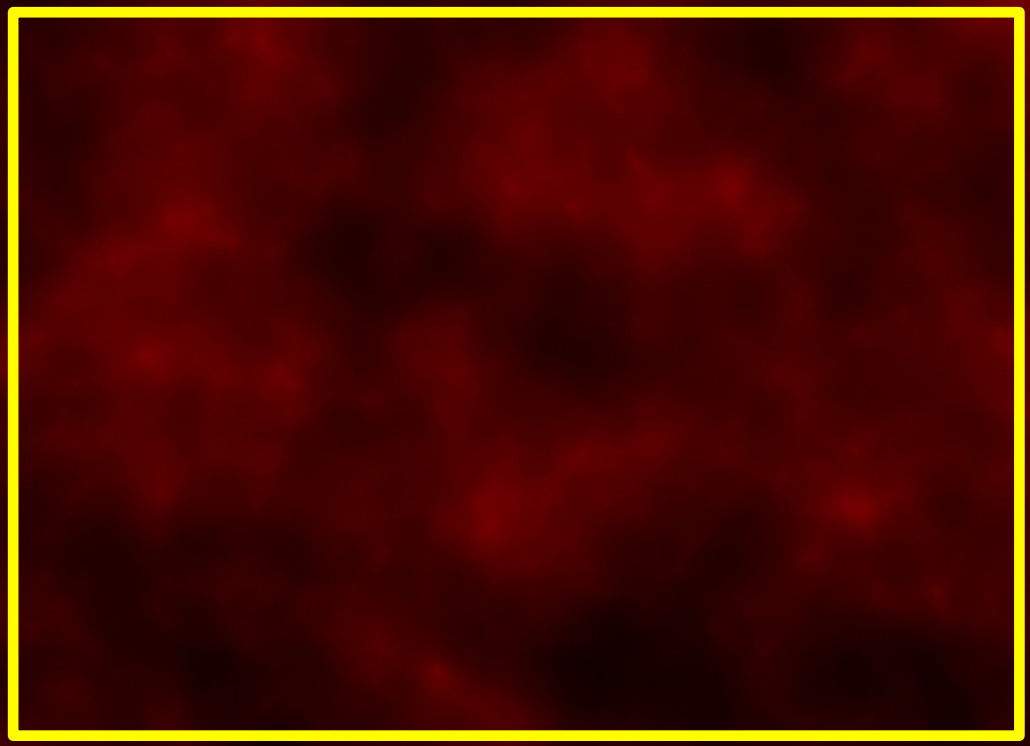
- From the potential we then calculate the Temperature:

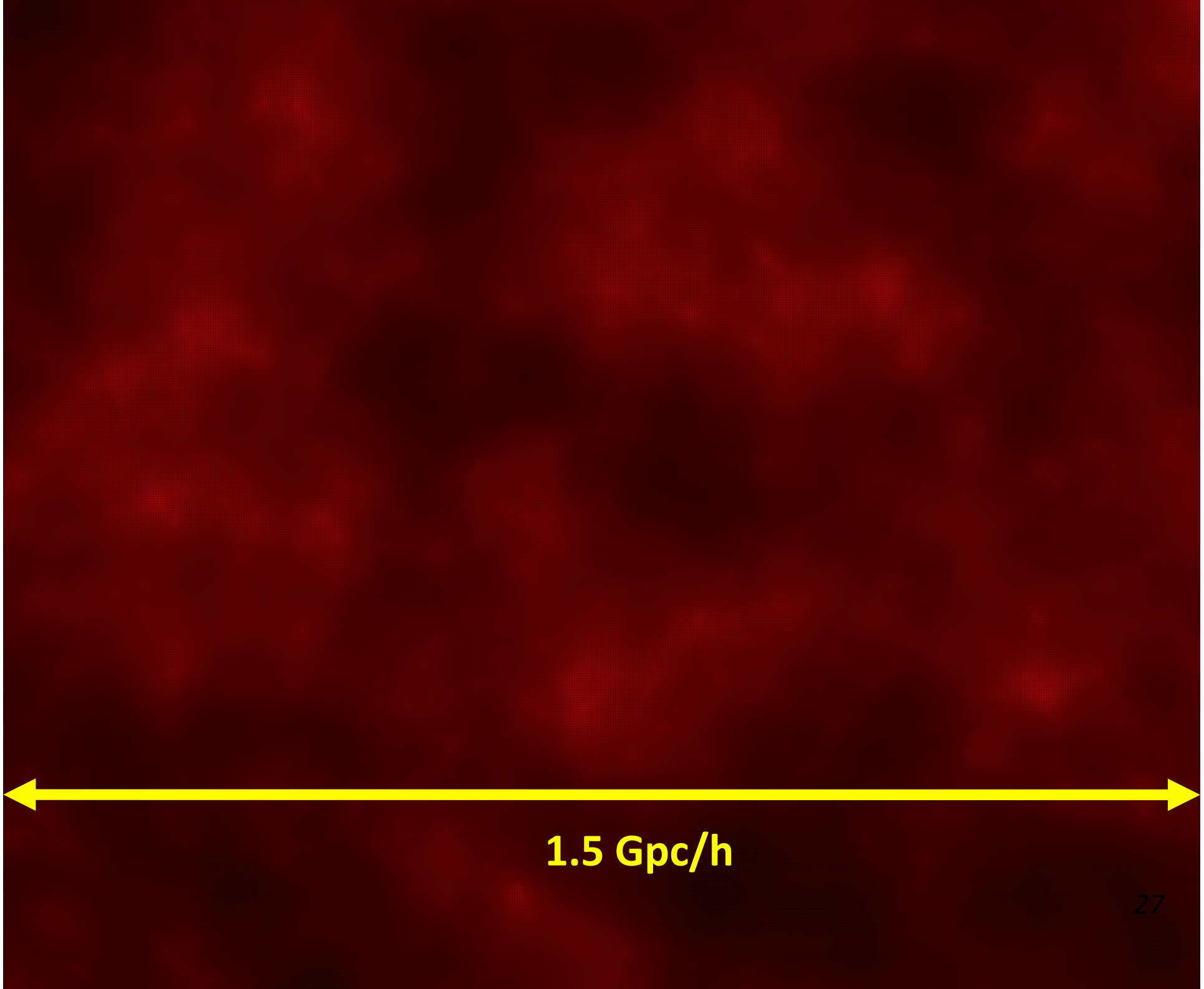
$$\Delta T(\hat{n}) = \frac{2}{c^3} \bar{T}_0 \int_0^{r_L} \dot{\Phi}(r, \hat{n})\, a\, dr$$


6 Gpc/h




3 Gpc/h

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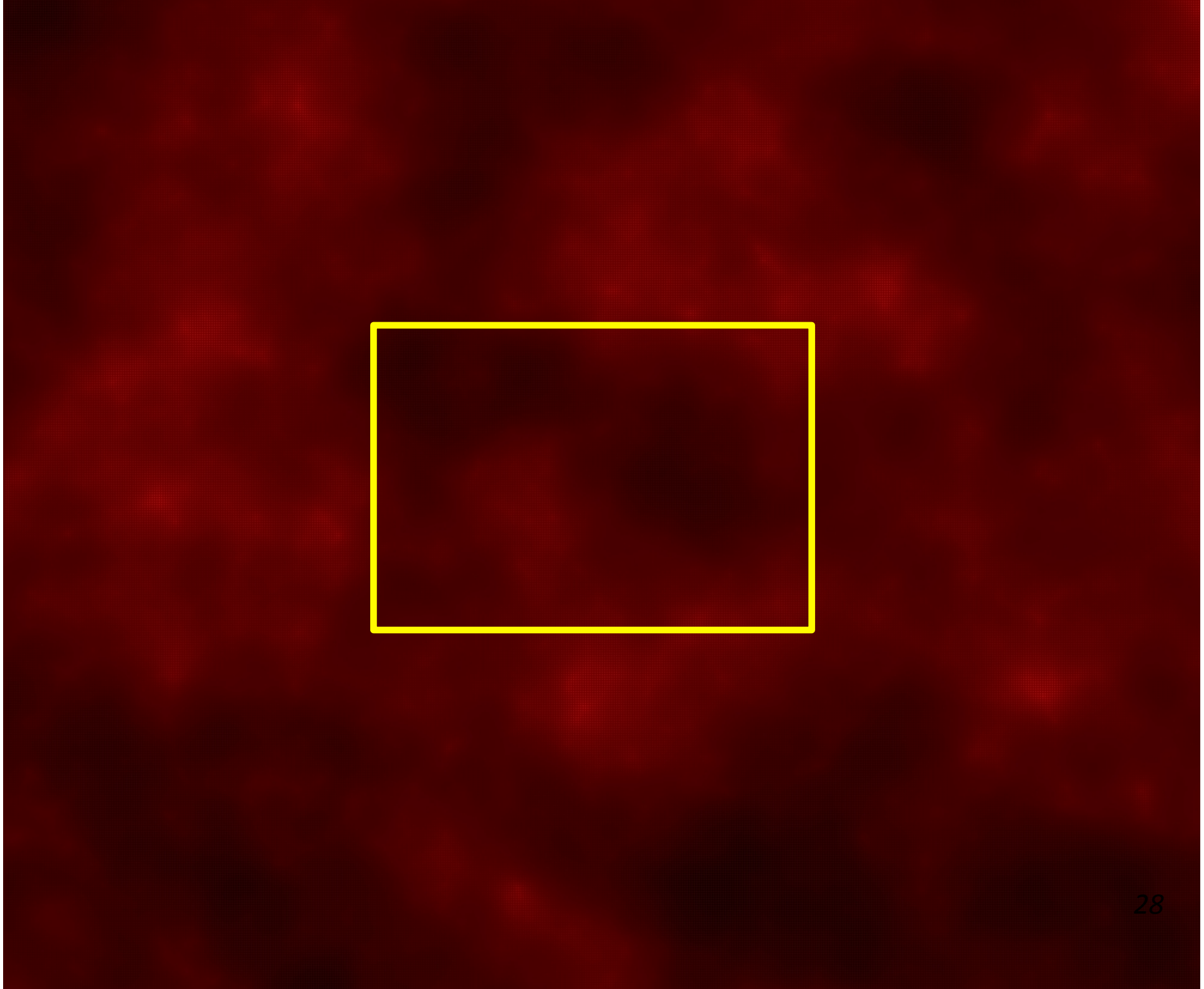
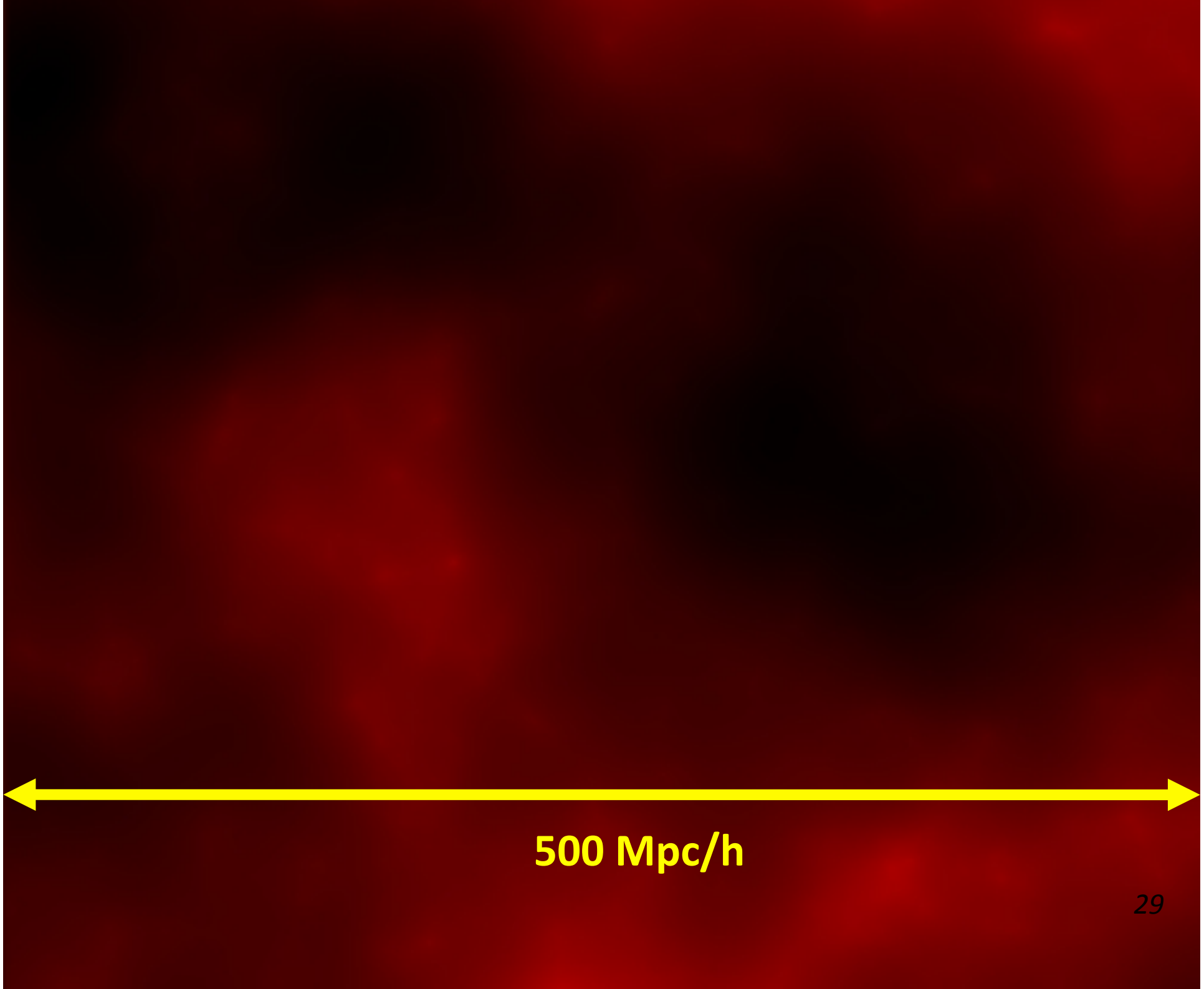
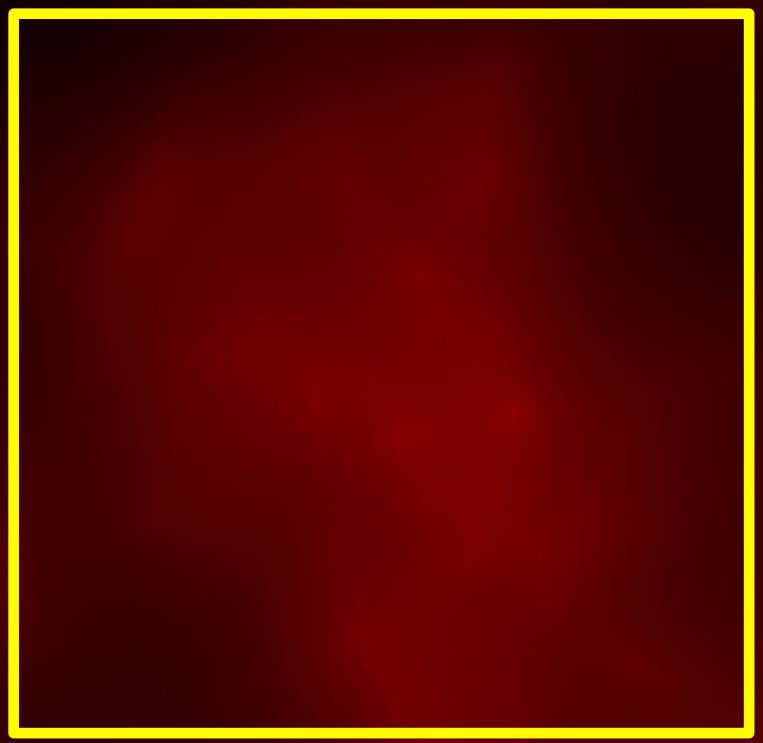
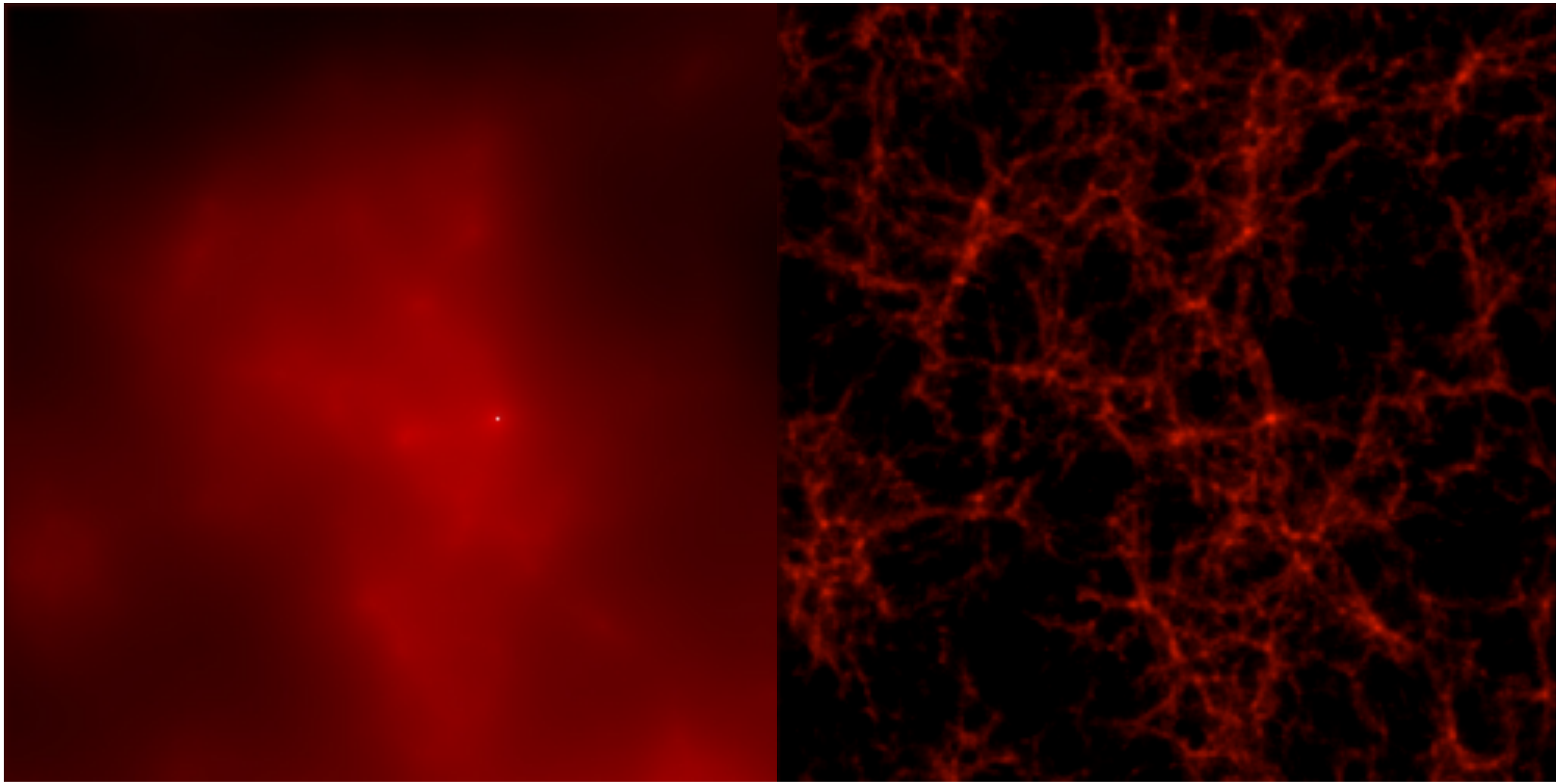
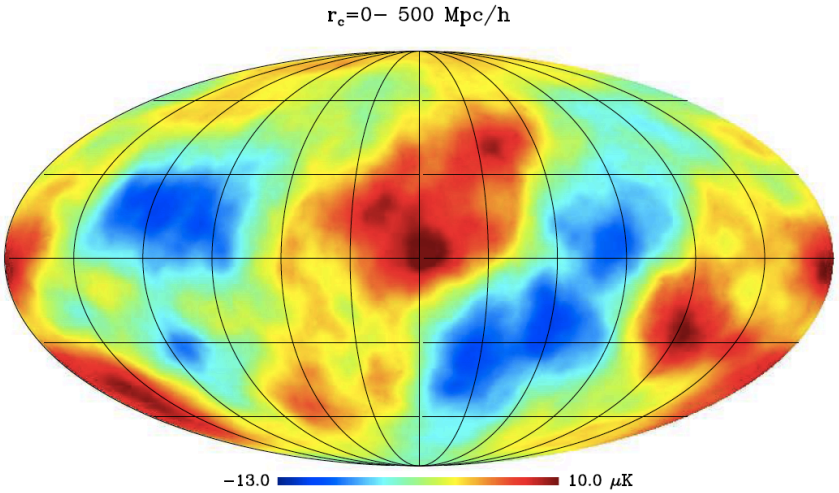


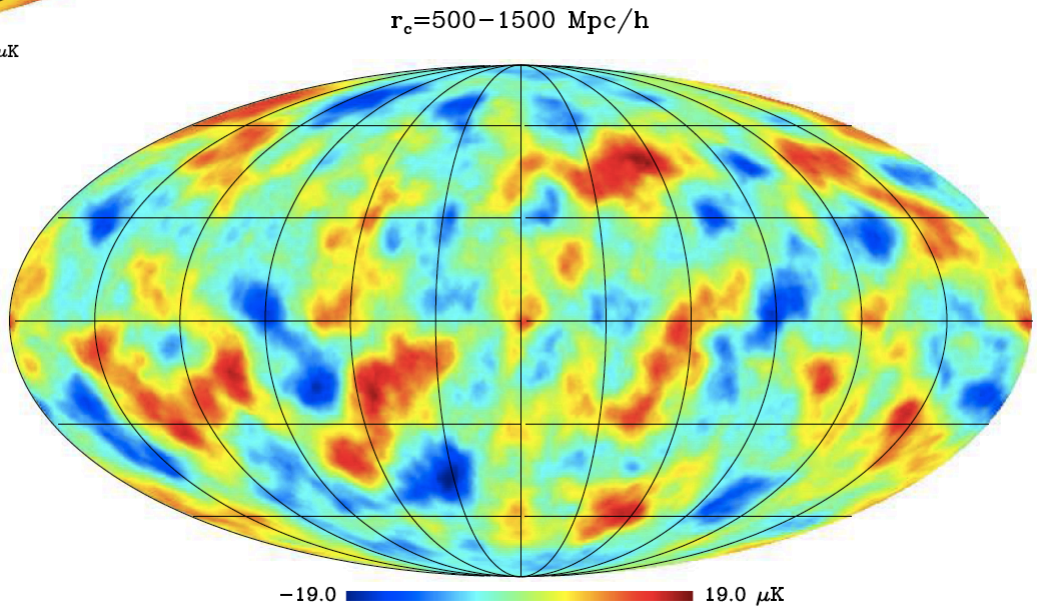

500 Mpc/h



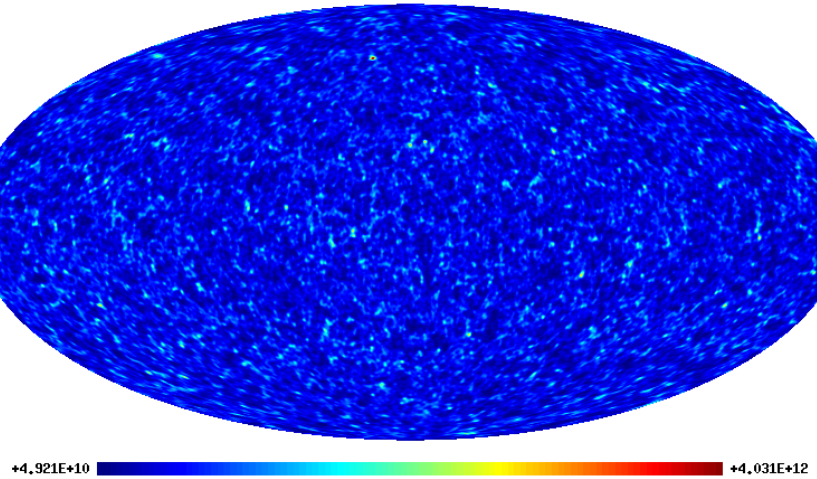


Cai et al. Maps

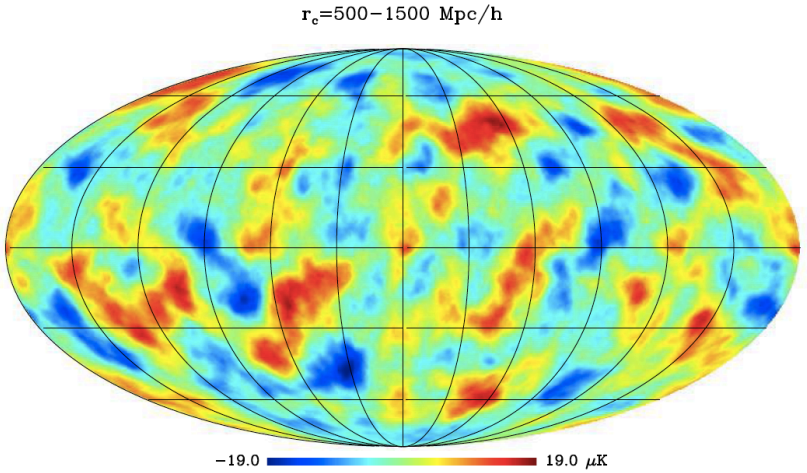




Cross Correlation With LRGs



Jubilee halos (z = 0.4)



Next Steps

- Complete remaining potentials from particle data (half done – each particle snapshot is 5 Tb)
- Produce full sky maps of density and potential fields (not vital – nice to have)
- Convert potential into ISW Temperature maps
- Produce full sky maps of LRGs from halo catalogues
- Cross correlate to ISW signal