

A visualization of the cosmic web, showing a complex network of dark matter filaments and clusters against a blue background. The filaments are represented by black and dark blue lines, forming a web-like structure. The background is a gradient of light to dark blue, with some white and light blue patches. The overall appearance is that of a vast, interconnected network of matter in the universe.

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# The cosmic web revisited

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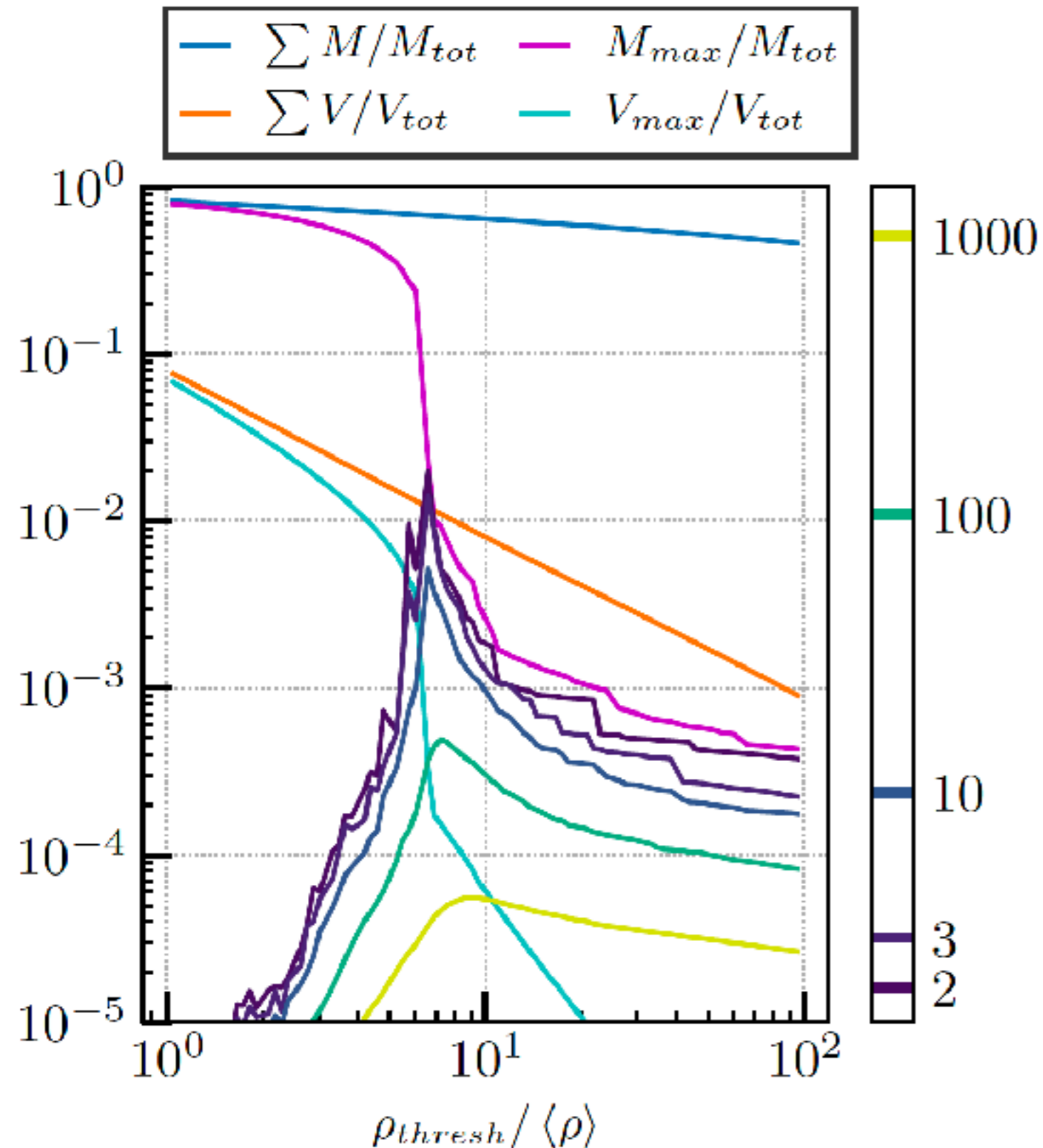
# From the Voronoi density field to halos and the Web

For a large-scale cosmological N-body simulation of the dark matter distribution

1. Make a Voronoi tessellation of the N-body particle distribution
2. Define the density associated with particle  $i$  by  $\rho_i = m_p/V_i$
3. Define particles  $i$  and  $j$  to be “friends” if their Voronoi cells share a face
4. Consider the set of all particles with density  $\rho_i$  greater than a threshold  $\rho_{\text{thresh}}$
5. Partition this set into “friends-of-friends” groups

For  $\rho_{\text{thresh}} \sim 80\langle\rho\rangle$  these groups are almost identical to standard FOF halos with  $b = 0.2$

# The cosmic web as the percolating DM structure



## The Millennium Simulation

$$L = 500 h^{-1} \text{Mpc}, \quad m_p = 8.6 \times 10^8 h^{-1} M_{\odot}$$

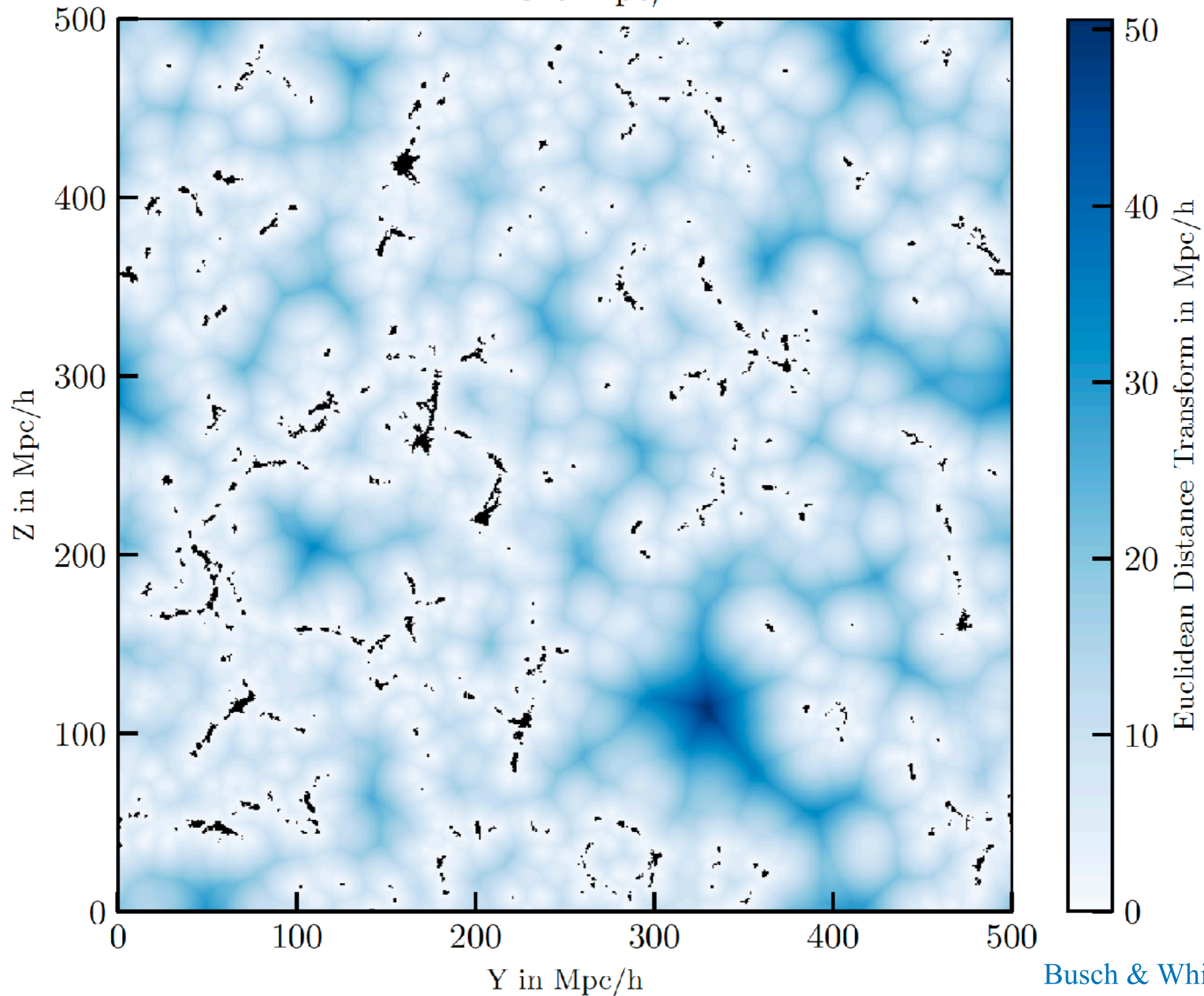
$$M_{\text{tot}} = 8.6 \times 10^{18} h^{-1} M_{\odot}$$

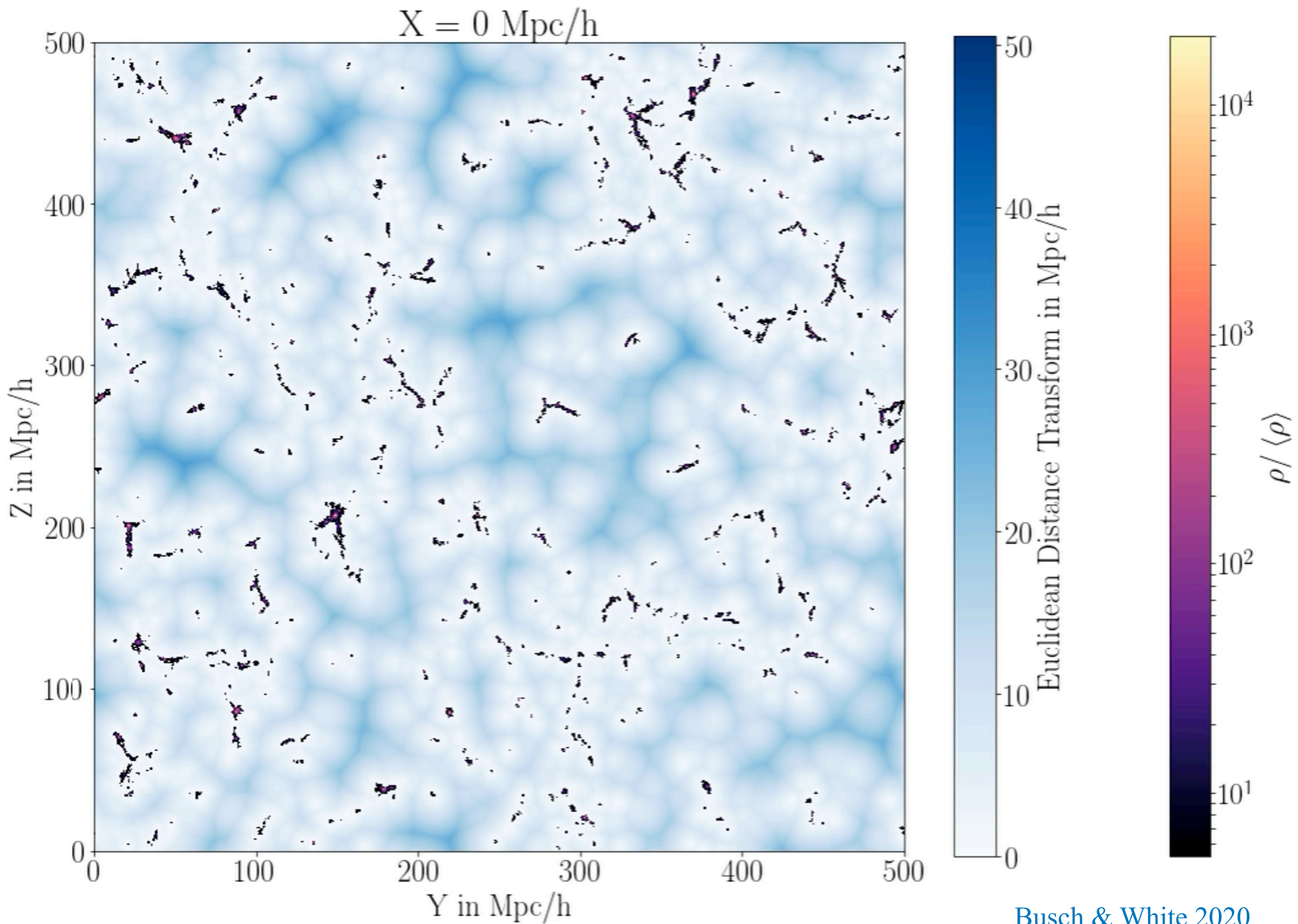
Percolation occurs for  $\rho_{\text{thresh}} \sim 7 \langle \rho \rangle$

For  $\rho_{\text{thresh}} = 5.25 \langle \rho \rangle$ , the “cosmic web” (CW) contains 35% of all mass in 0.62% of all volume.

- This defines the CW as a material object
- It is bounded by an equidensity surface
- Every particle/halo is either in the CW or not

$X = 318 \text{ Mpc}/h$





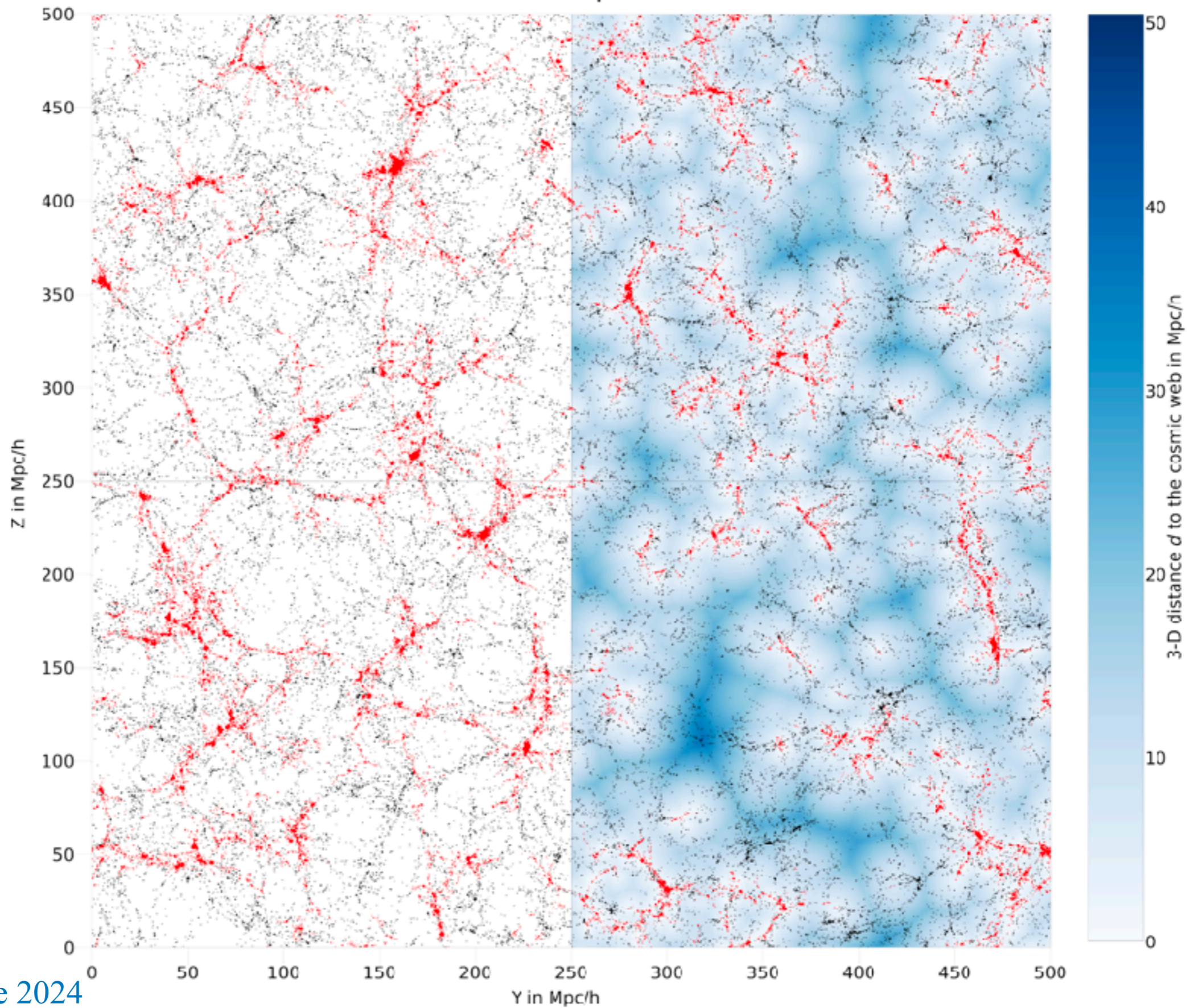
# Galaxies and the Web

$X = 318 \text{ Mpc}/h$

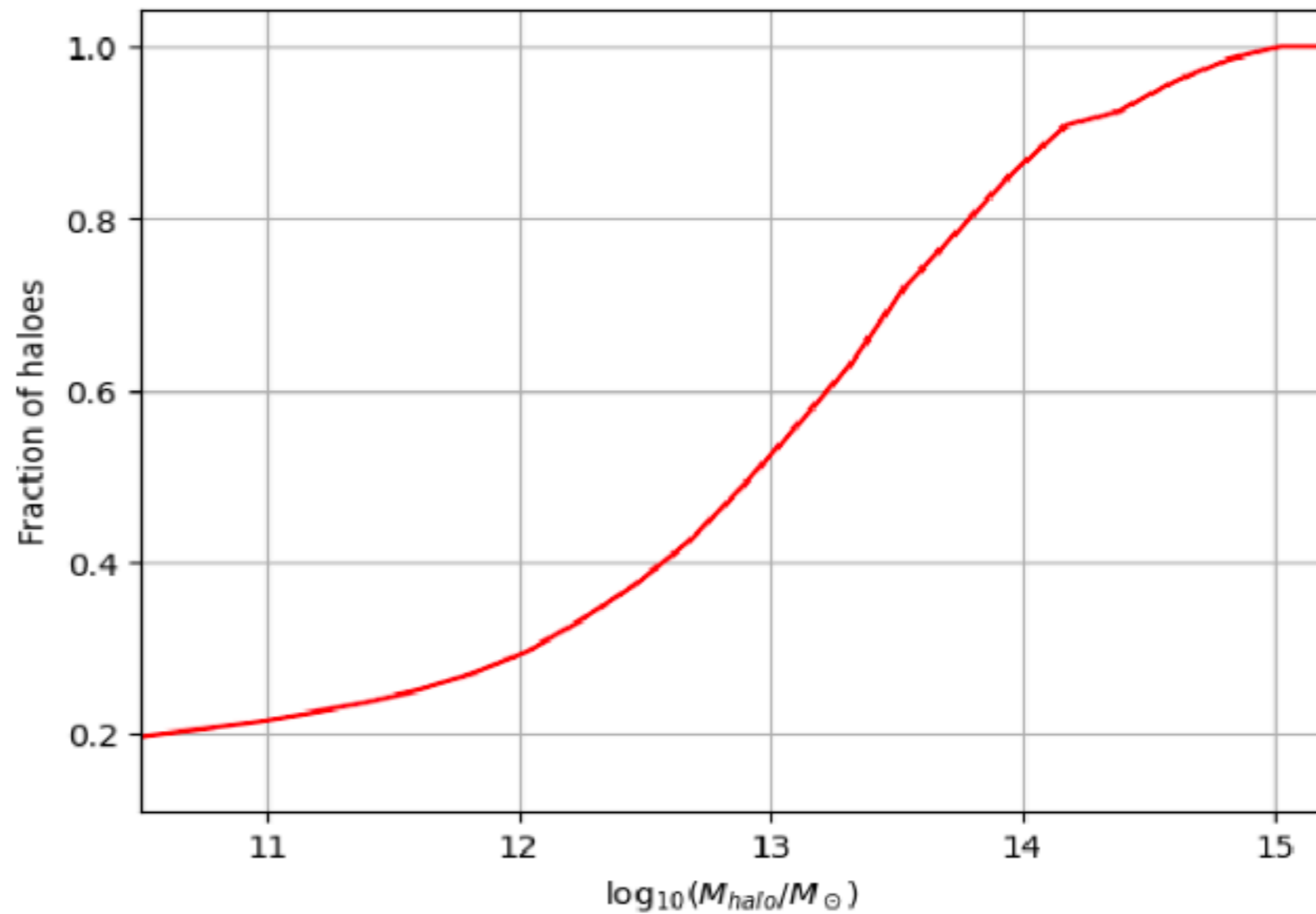
$$M_* > 10^{9.5} h^{-1} M_\odot$$

$$\Delta X = 20 h^{-1} \text{Mpc}$$

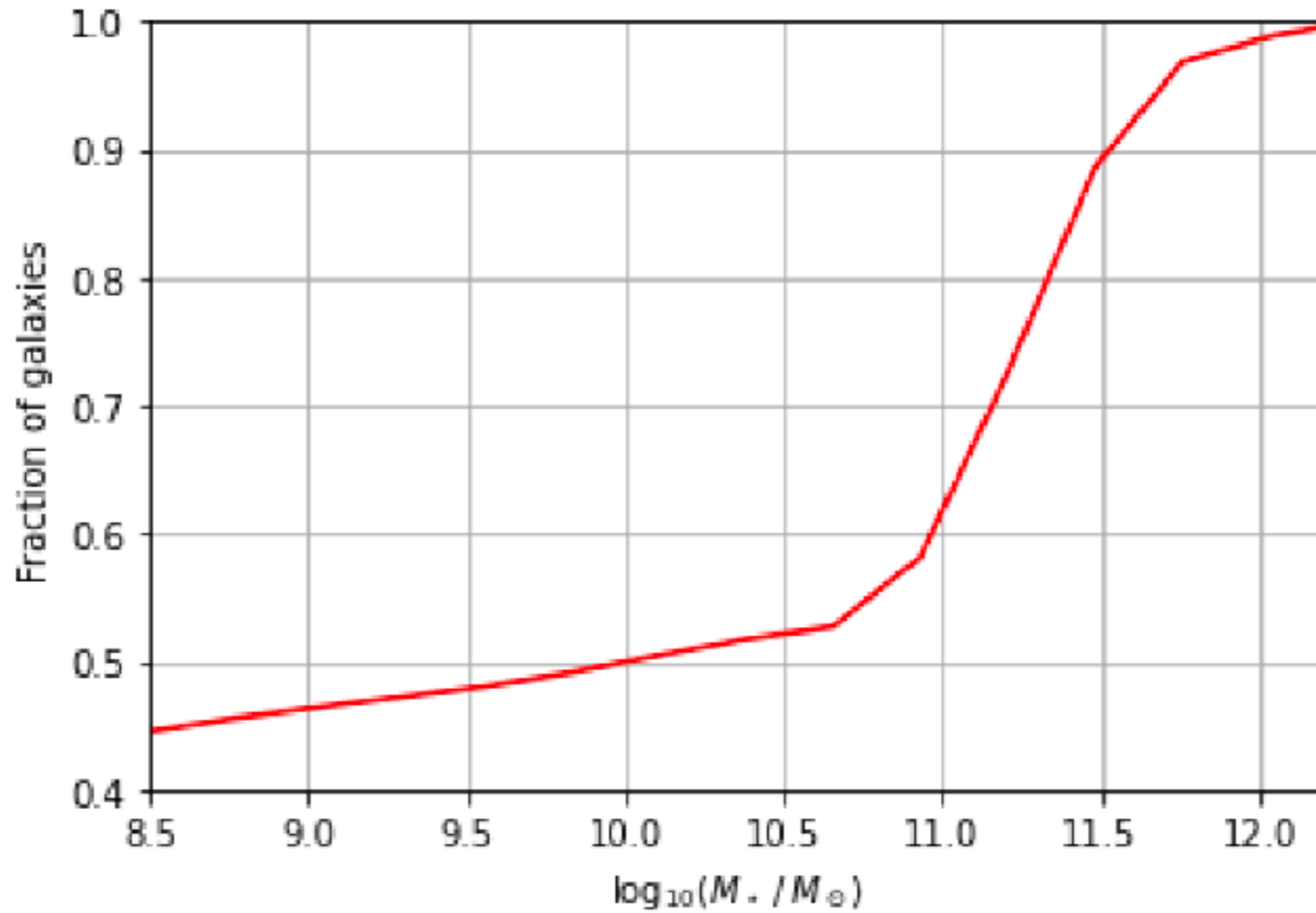
$$\rho_{\text{thresh}} = 5.25 \langle \rho \rangle$$



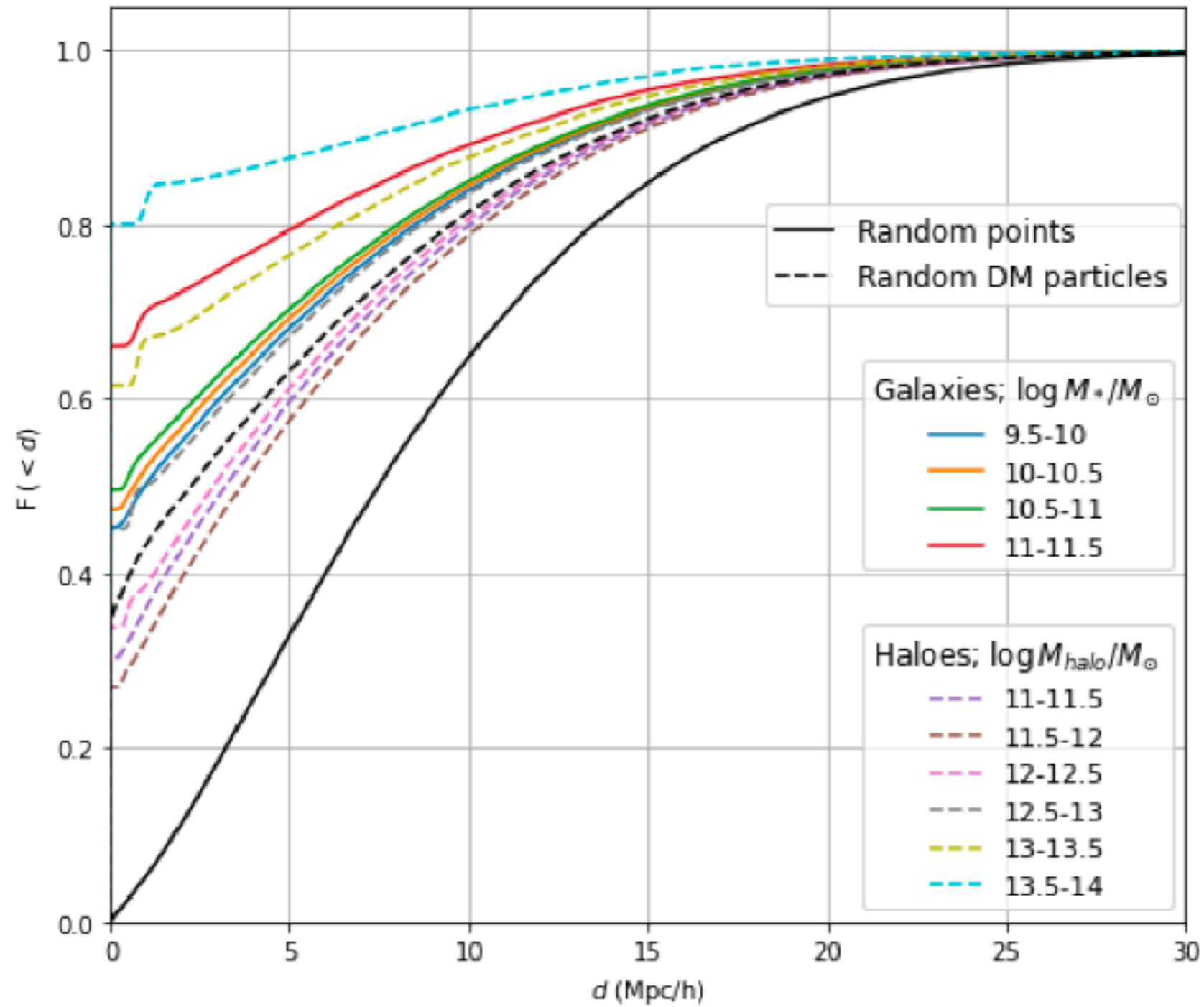
# The fraction of halos in the CW as a function of mass $M_{200}$



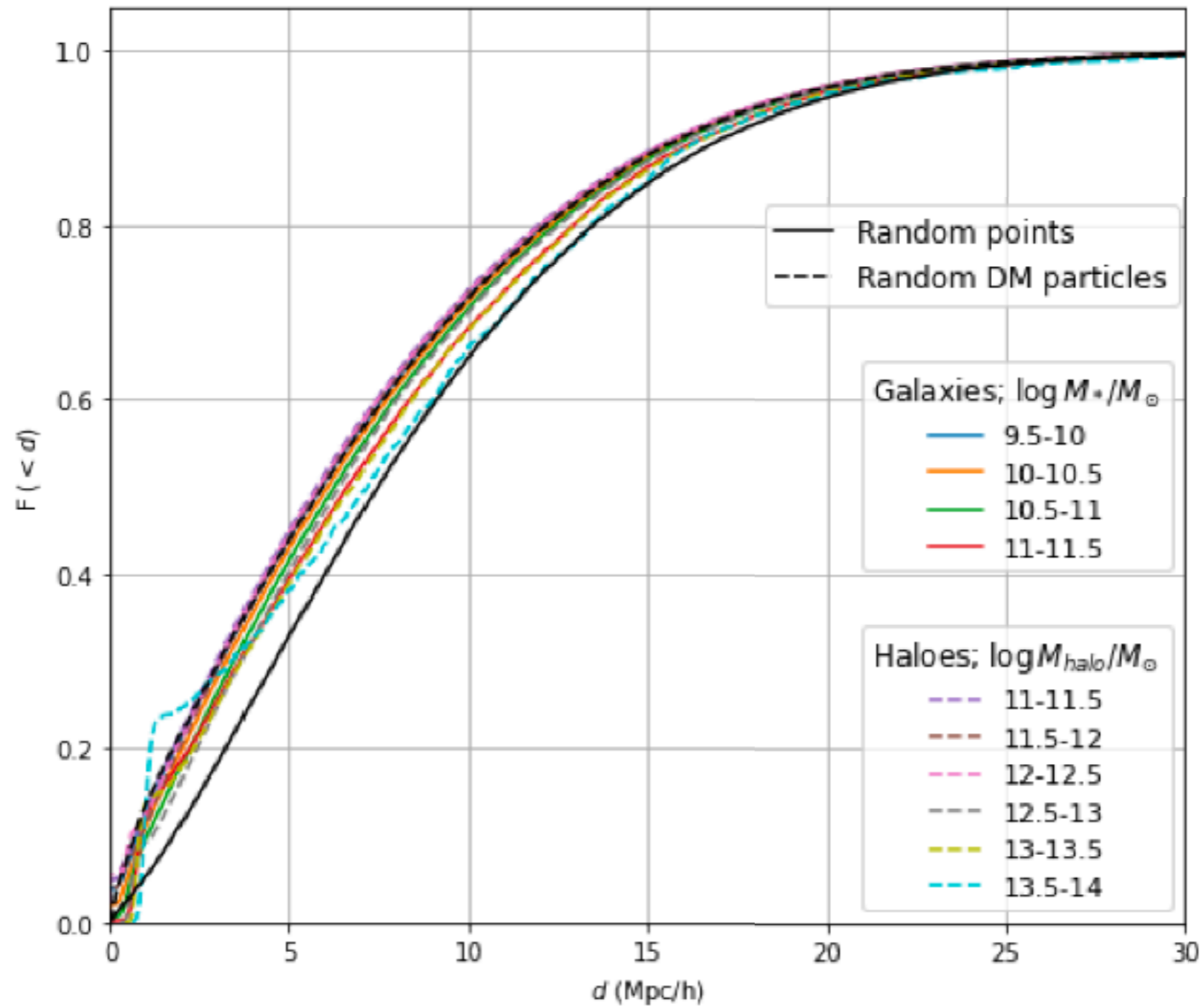
# The fraction of galaxies in the CW as a function of stellar mass



# Distance of objects to the nearest point in the CW

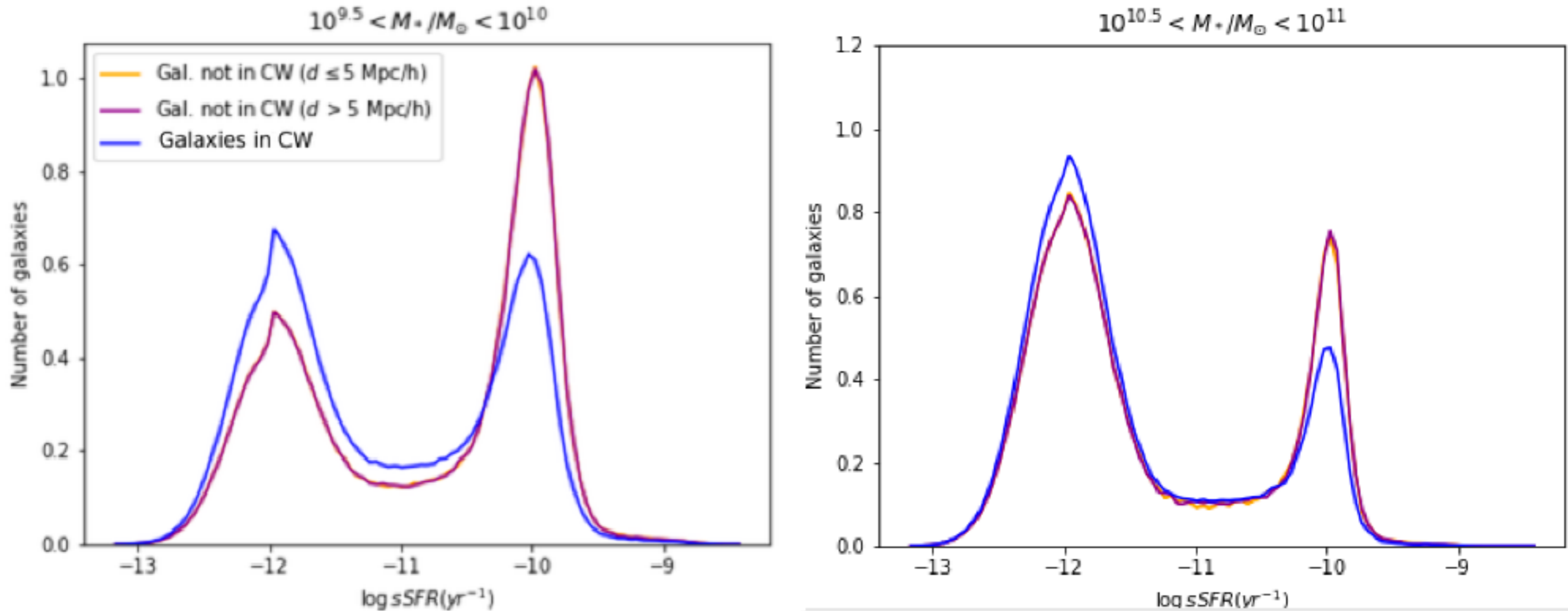


# Distance of non-web objects to the nearest point in the CW



Non-web galaxies and halos of all masses have nearly the same distribution of distance to the web as non-web dark matter

# Specific star formation rate distributions vs web distance



- The fraction of passive galaxies is greater in the cosmic web than outside it at all stellar masses
- For non-web galaxies the passive fraction is independent of distance from the cosmic web
- The passive excess in the CW is mainly due to the satellite fraction being 2 to 3 times larger there