PRECISE summer school
Warsaw

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hands-on cosmological simulations

session 3: identifying structures & basic predictions of simulations

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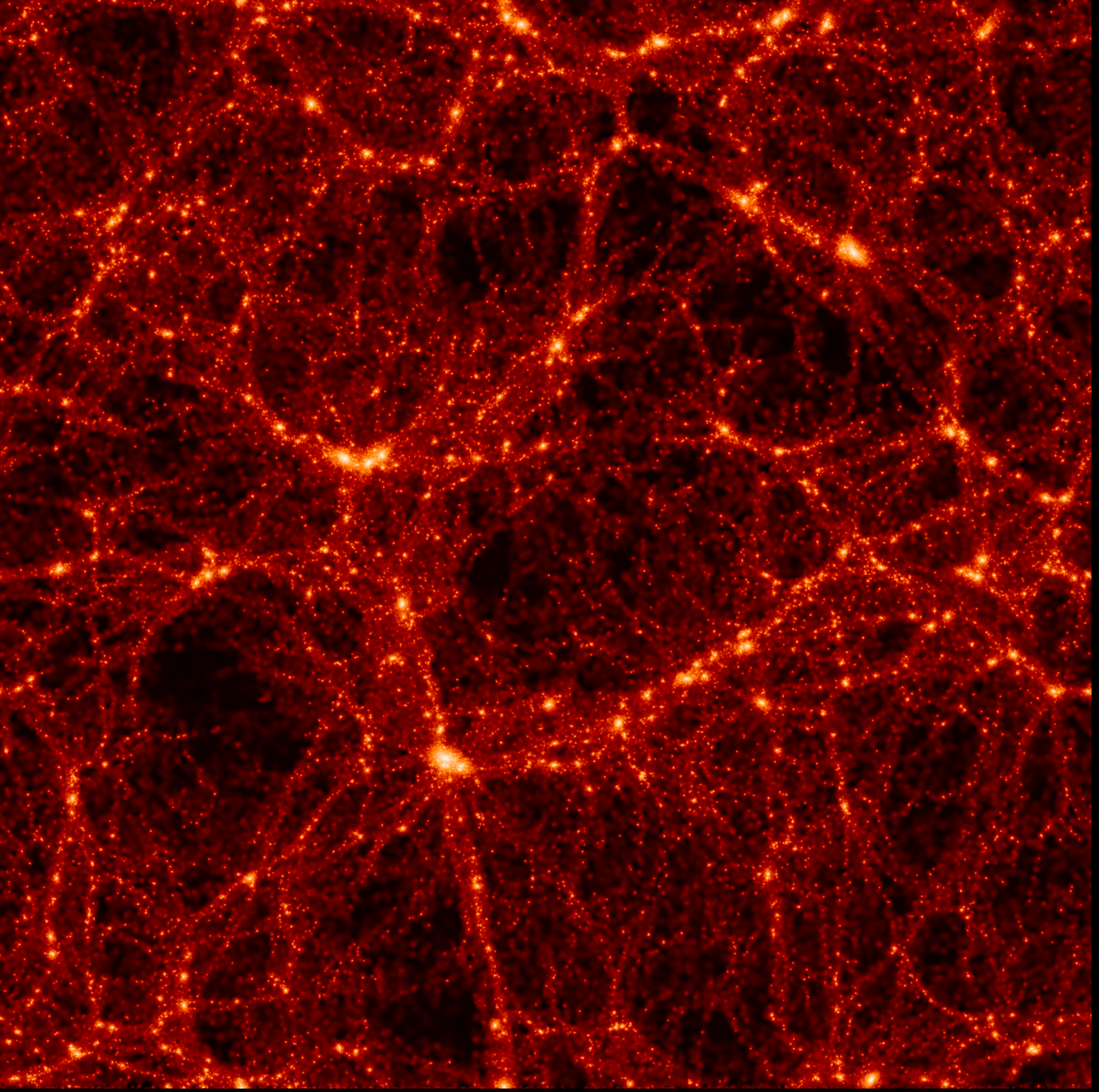
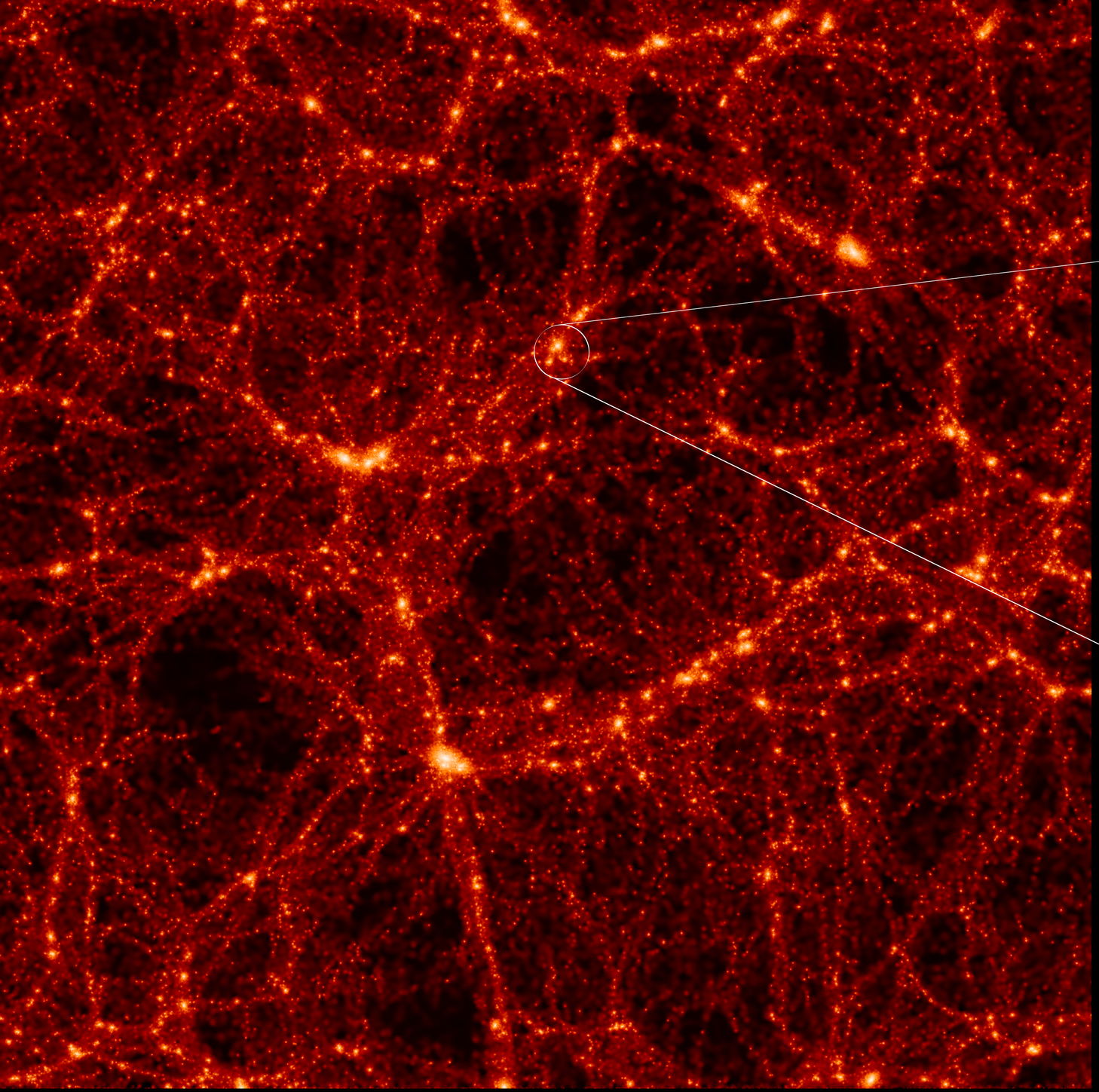
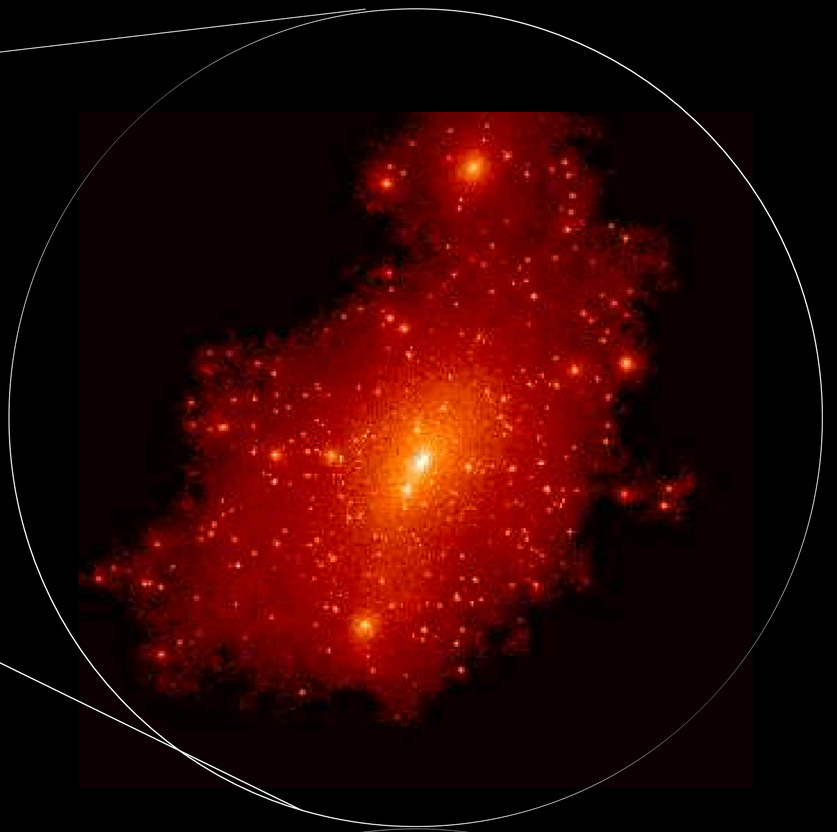
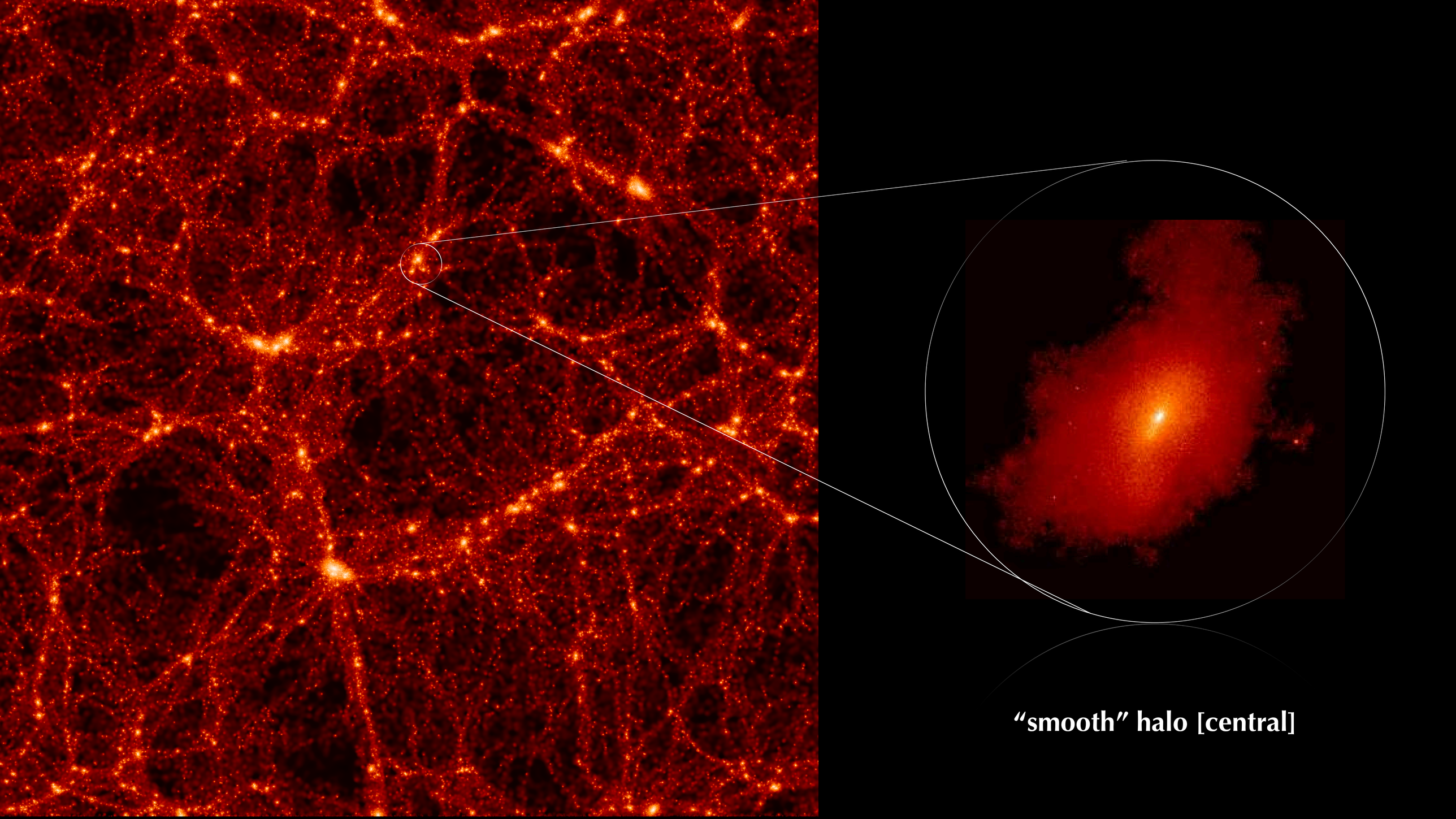
identifying haloes & bound structures

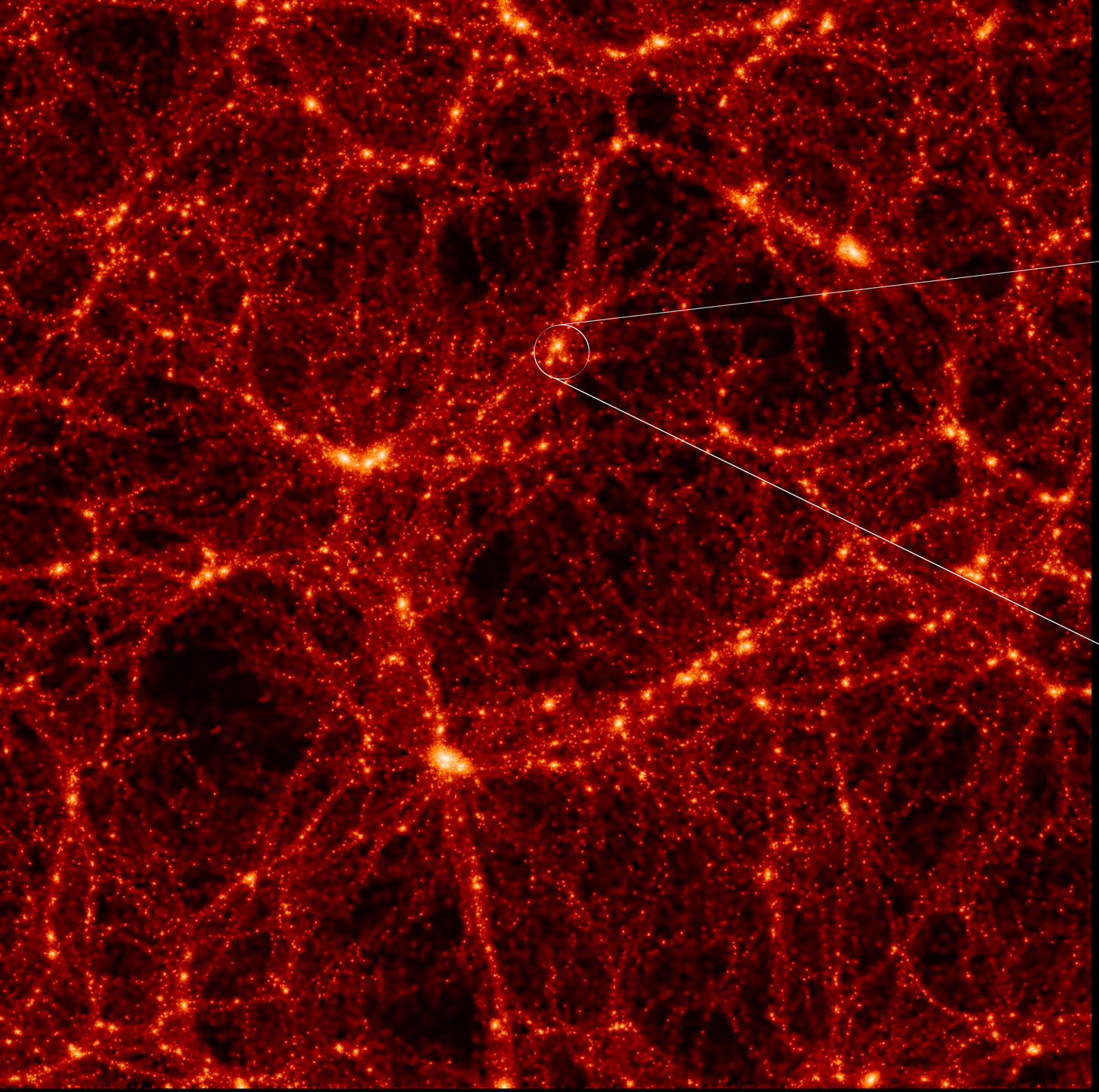


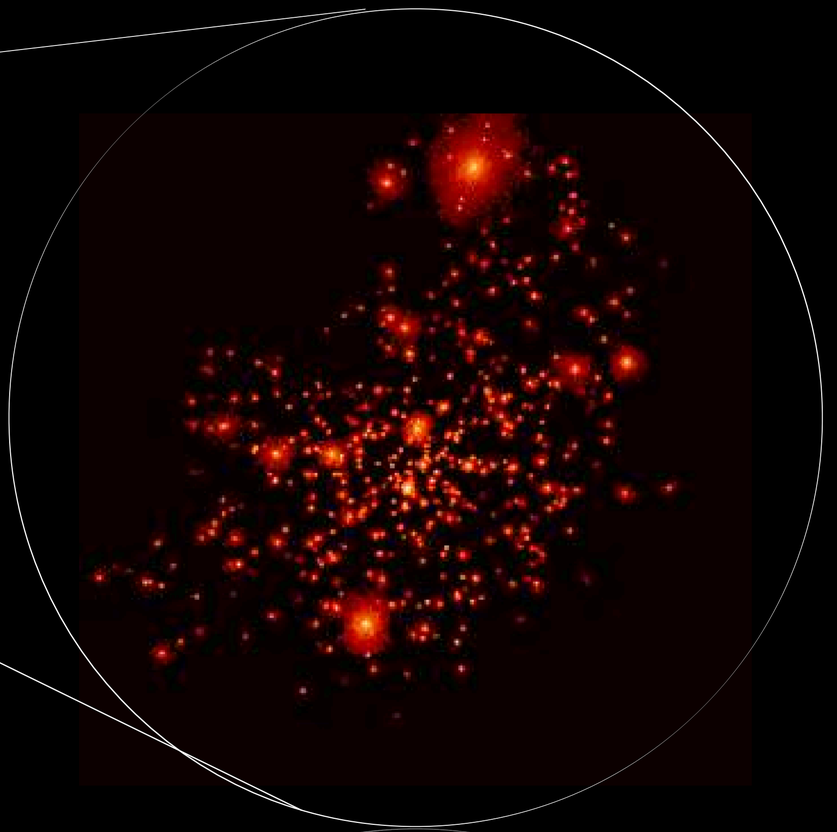




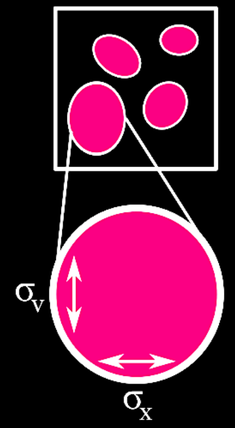
friends-of-friends halo


“smooth” halo [central]





substructures [satellites]



1. The simulation volume is divided into 3D Friends-of-Friends groups for easy parallelization.

2. For each group, particle positions and velocities are divided (normalized) by the group position and velocity dispersions, giving a natural phase-space metric.

3. A phase-space linking length is adaptively chosen such that 70% of the group's particles are linked together in subgroups.

4. The process repeats for each subgroup: renormalization, a new linking-length, and a new level of substructure calculated.

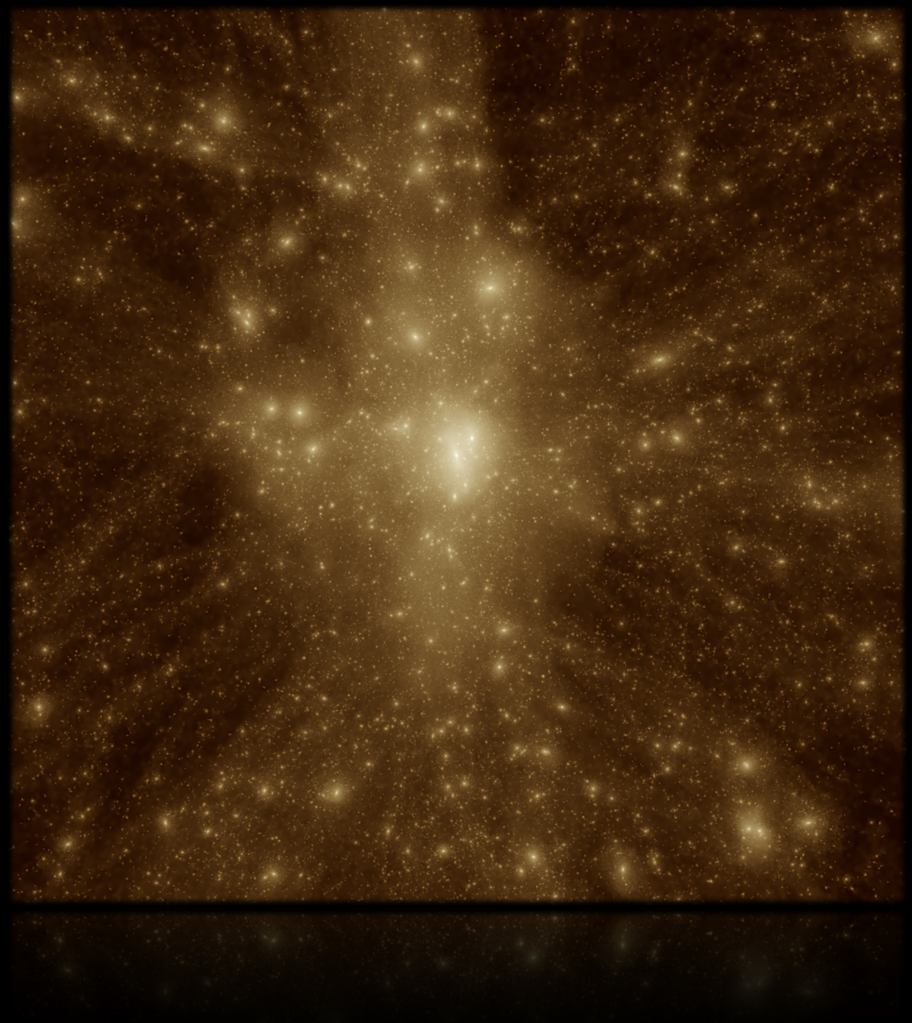
5. Once all levels of substructure are found, seed halos are placed at the lowest substructure levels and particles are assigned hierarchically to the closest seed halo in phase space.

6. Once particles have been assigned to halos, unbound particles are removed and halo properties (positions, velocities, etc.) are calculated.

6D phase-space structure finding not always used

Behroozi+ (2013)

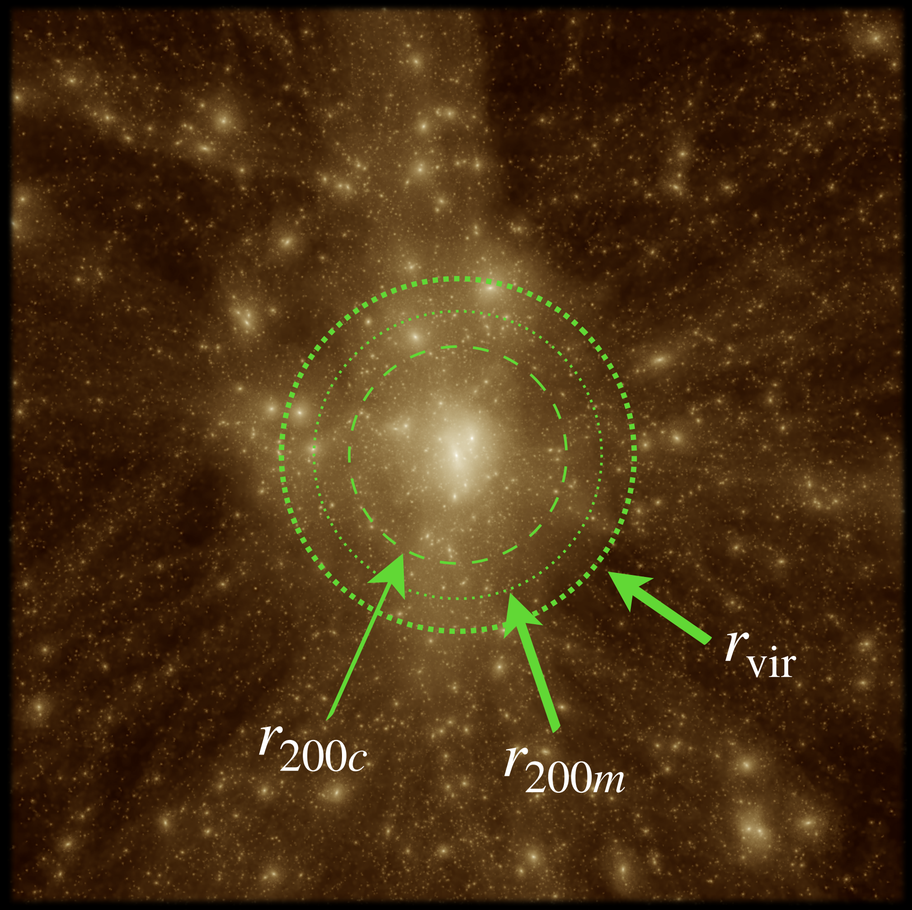
definitions of halo mass



DM haloes identified in N-body simulations are highly irregular objects. how do we define their mass / extent?

⇒ do what astronomers do best and assume everything is spherical

definitions of halo mass



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$$M_\Delta = \frac{4}{3}\pi\Delta\rho_{\rm ref}r_\Delta^3 \text{ where } \bar{\rho}(<r_\Delta) = \Delta\cdot\rho_{\rm ref}$$

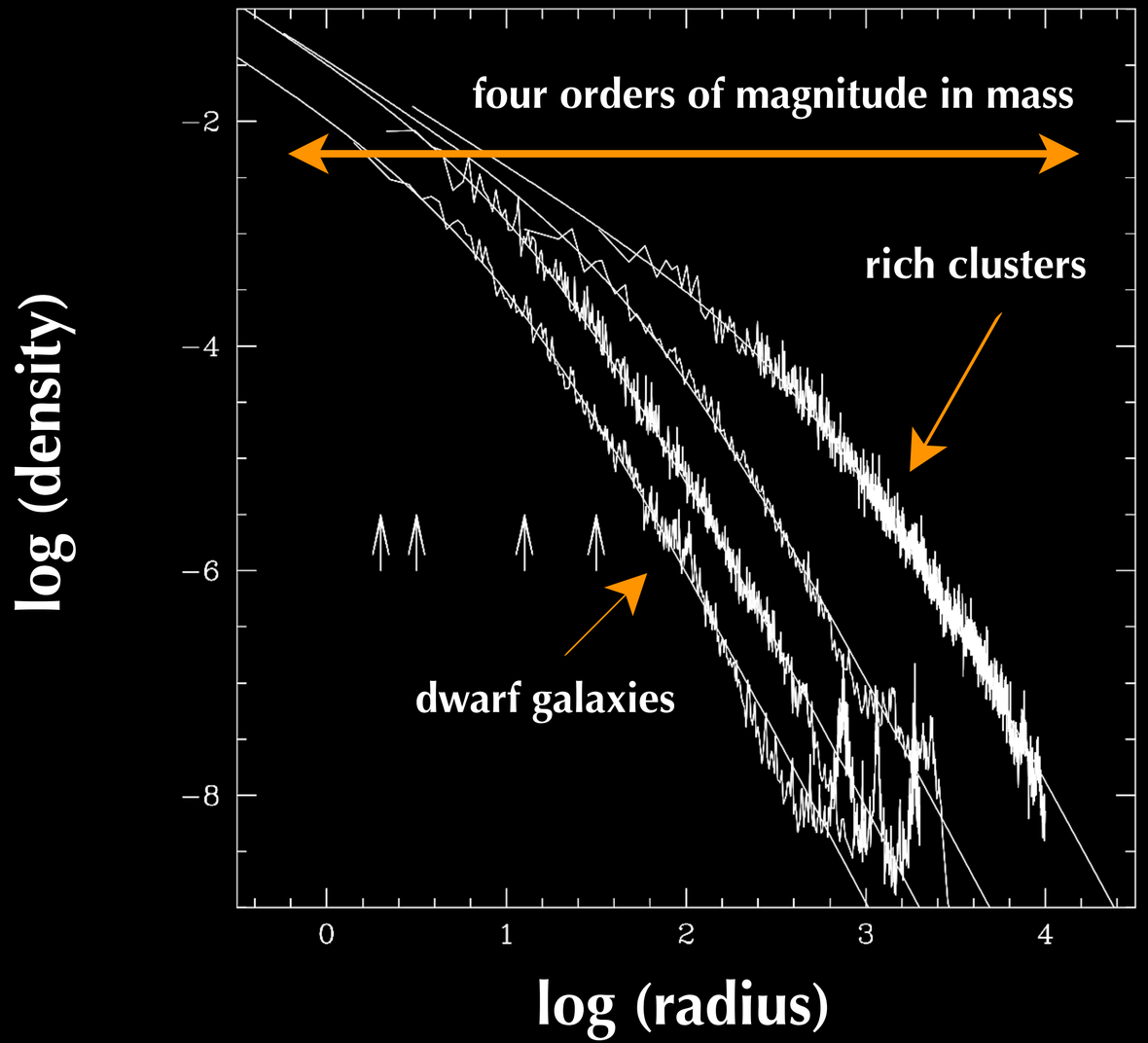
virial mass/radius

commonly used definitions

label	Δ	$\rho_{\rm ref}$	spherical	cosmology dependent?	binding information?
$M_{\rm FOF}$	–	–	✗	✓	✗
$M_{\rm sub}$	–	$\rho_{\rm host}$	✗	✗	✓
M_{200c}	**200**	$\rho_{\rm crit}$	✓	✓	✗
M_{200m}	**200**	$\rho_{\rm mean}$	✓	✓	✗
$M_{\rm vir}$	$18\pi^2 + 82x - 39x^2$ $x \equiv \Omega(z) - 1$	$\rho_{\rm mean}$	✓	✓	✗

some universal predictions

self-similar structure



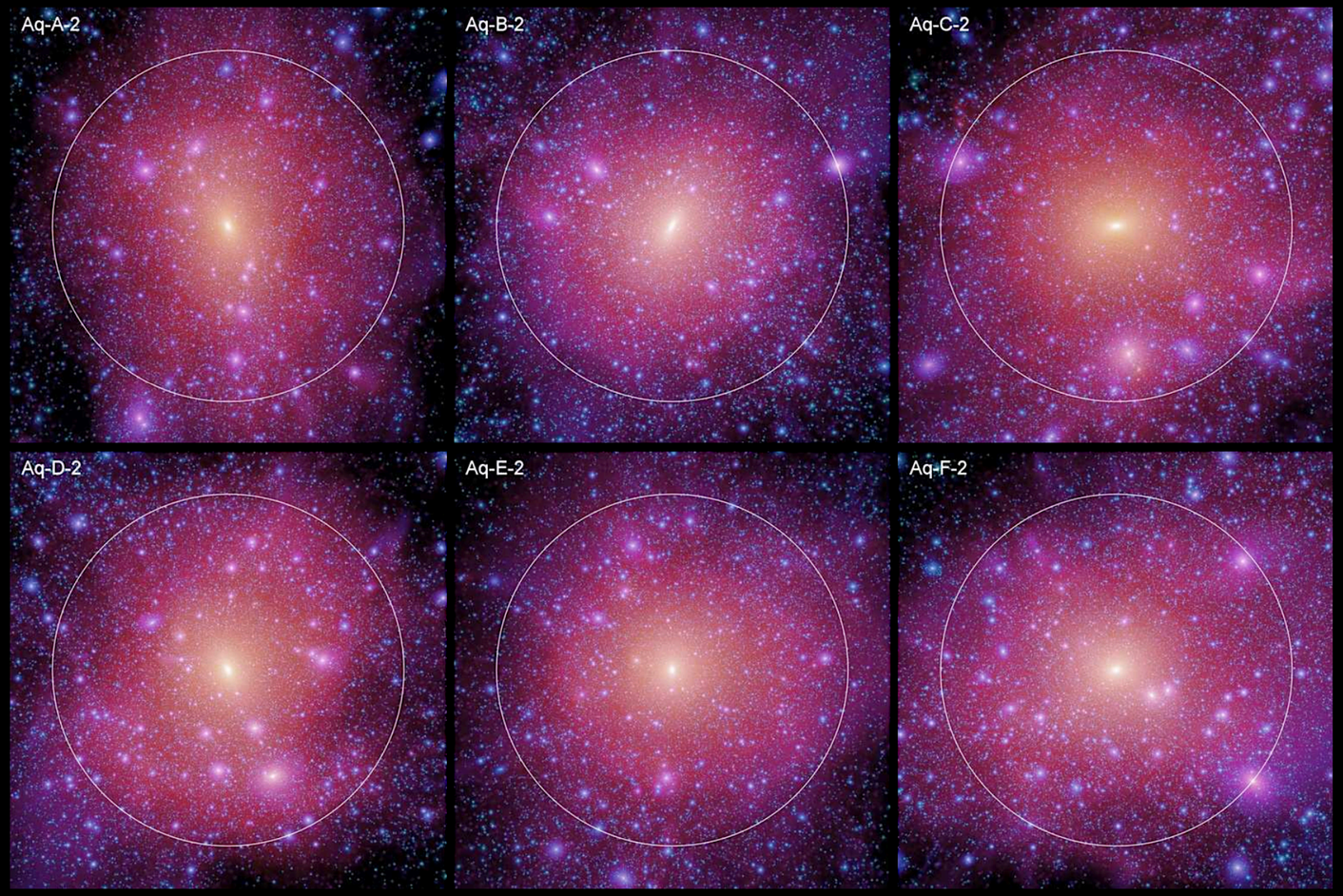
centre: $\rho \propto r^{-1}$

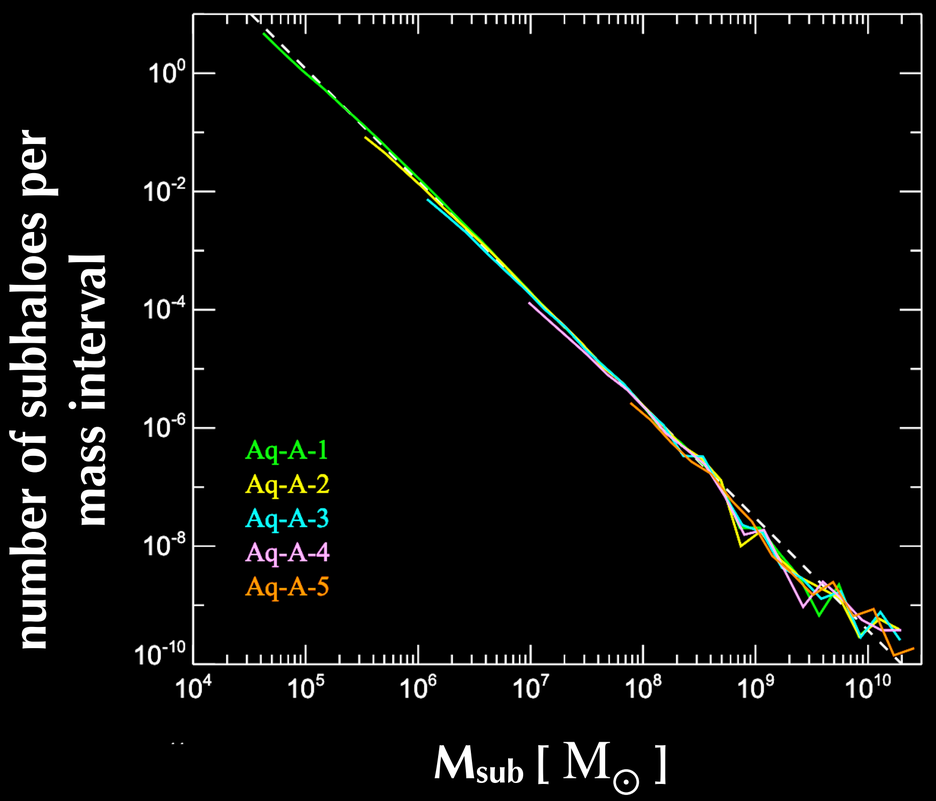
middle: $\rho \propto r^{-2}$

outskirts: $\rho \propto r^{-3}$

Navarro, Frenk & White (1996)

self-similar abundance





Springel+ (2008)

limits of N-body simulations