Substructure ++
(evolution and destruction of CDM substructure)

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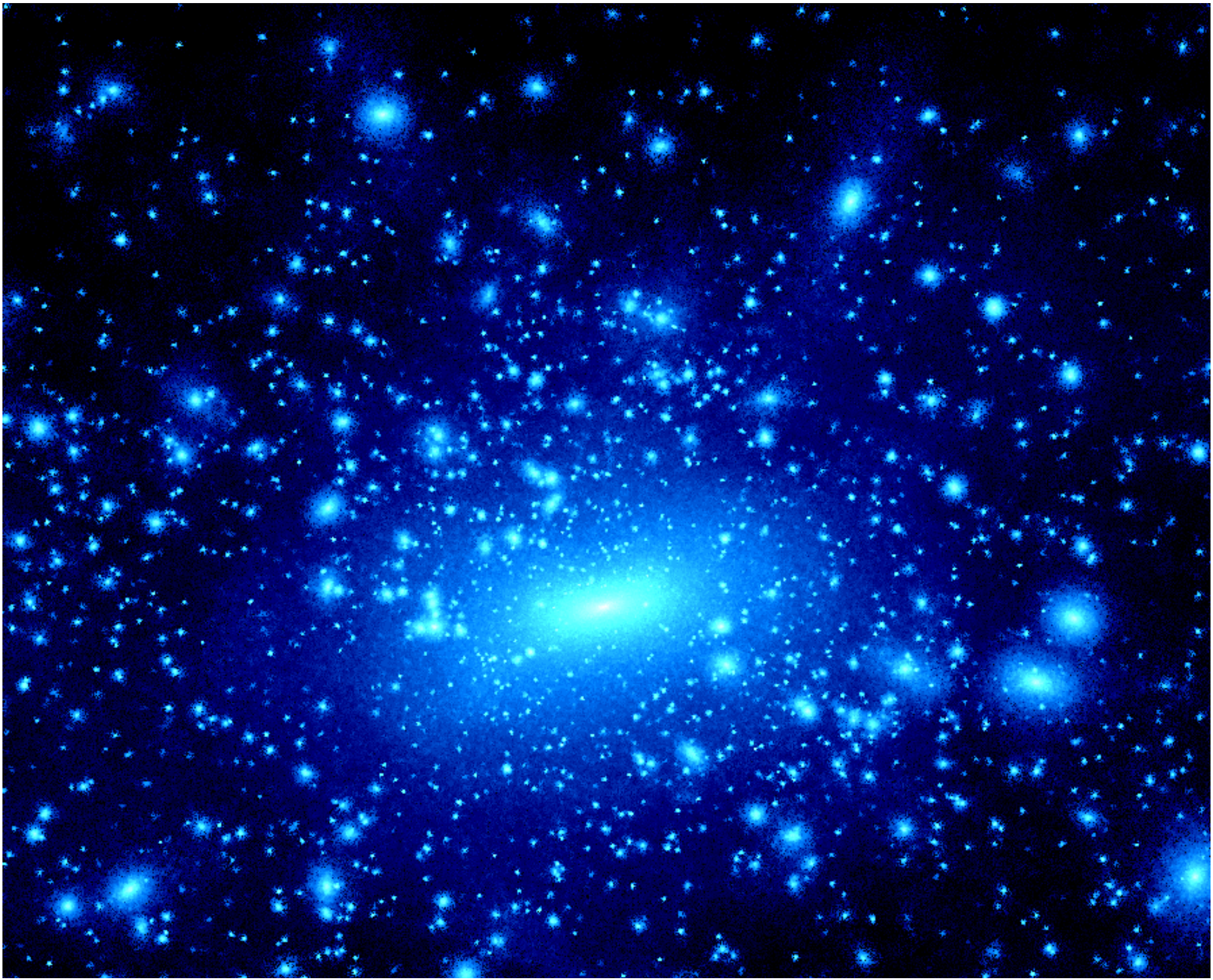
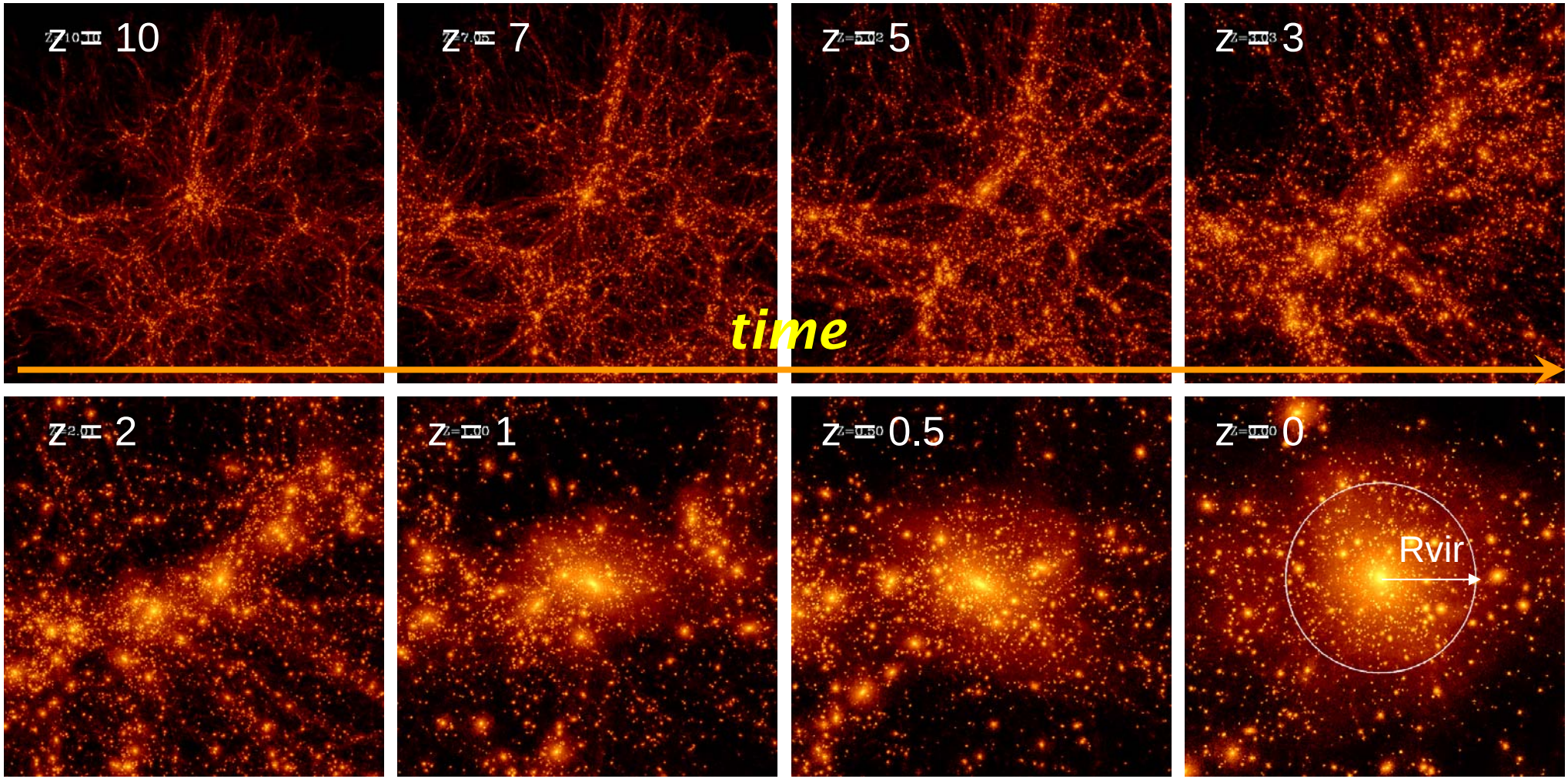


Abundance of subhalos in a given halo

is determined by competition between accretion of new subhalos and disruption of old subhalos

disruption = loss of identity via merging with other halos or significant mass loss due to tidal stripping



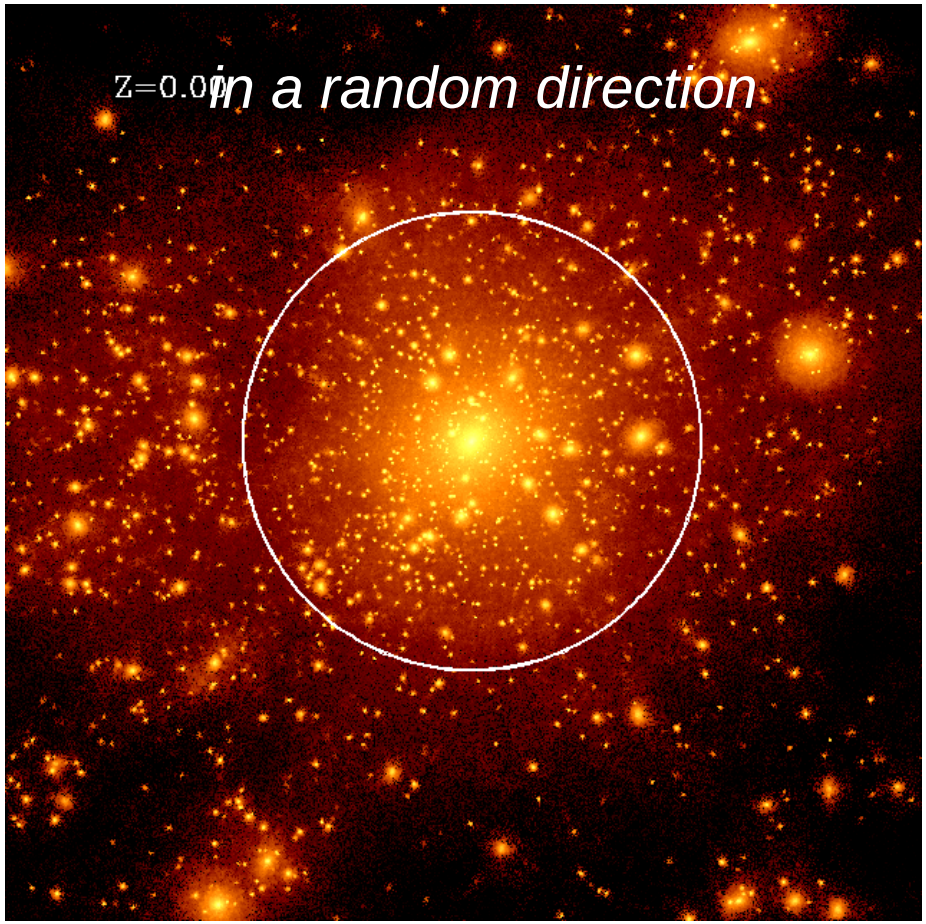
Formation of a galaxy-sized halo in LCDM, Mvir=3x$10^{12}h^{-1}$ Msun; Rvir=293h^{-1} kpc;

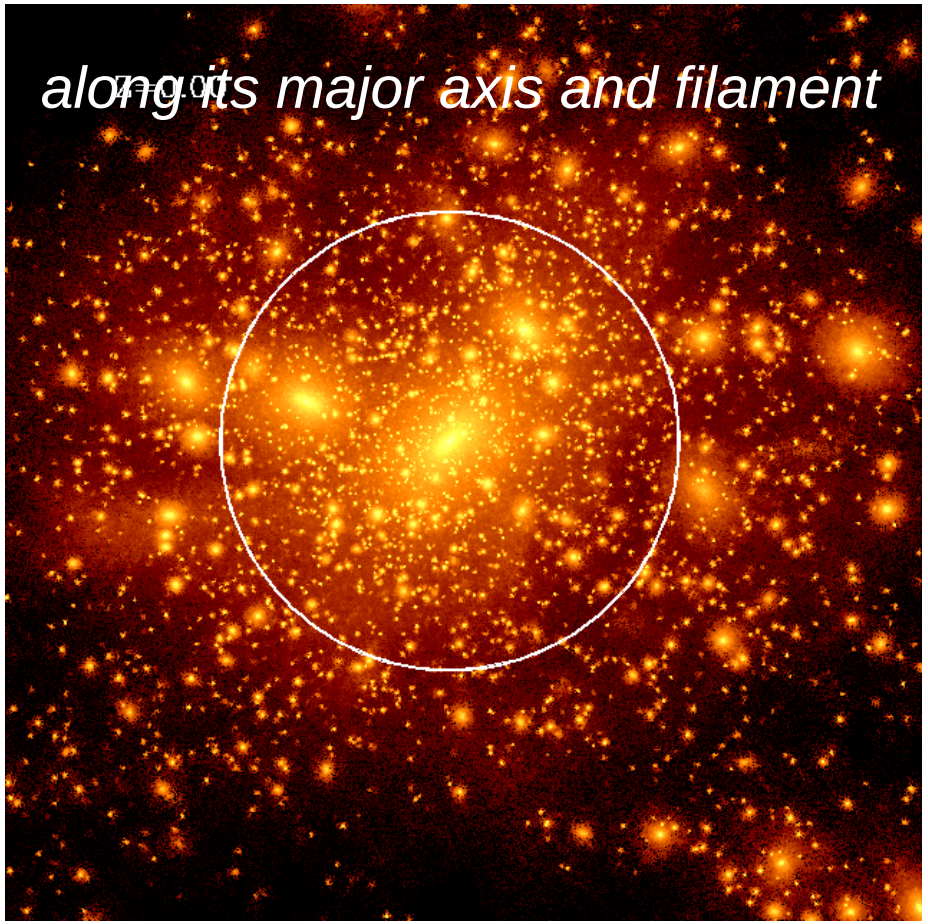
Halo Substructure

has anisotropic distribution

Zentner et al. 2005; Liebeskind et al. 2005

The same MW-sized halo viewed

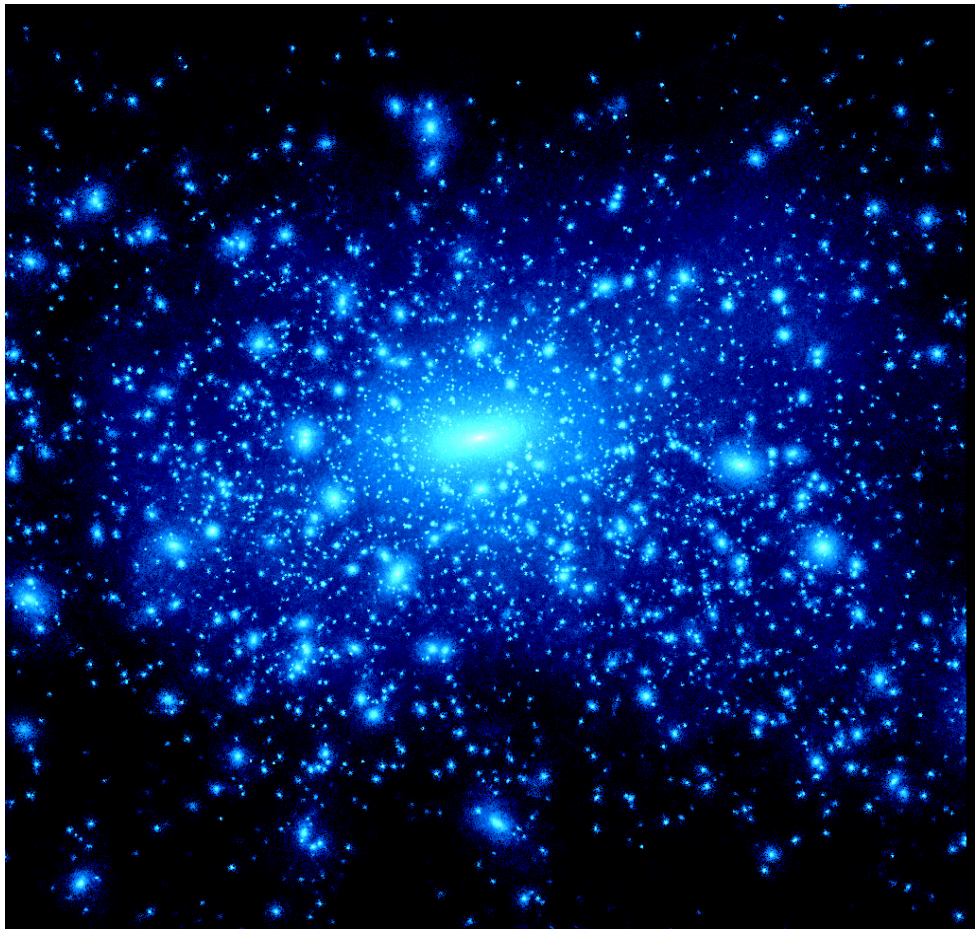


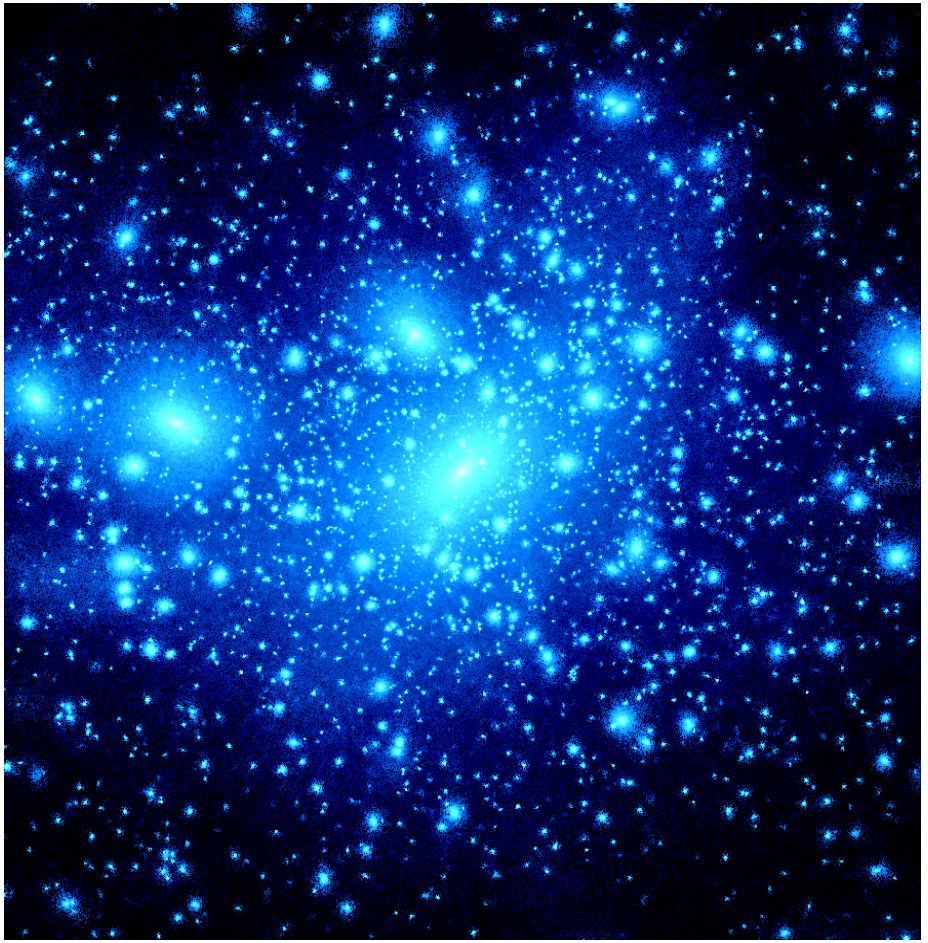


Halo Substructure

Approx. (but not exactly) self-similar

e.g., Ghigna et al. 2000; Gao et al. 2005





A cluster or a galaxy?

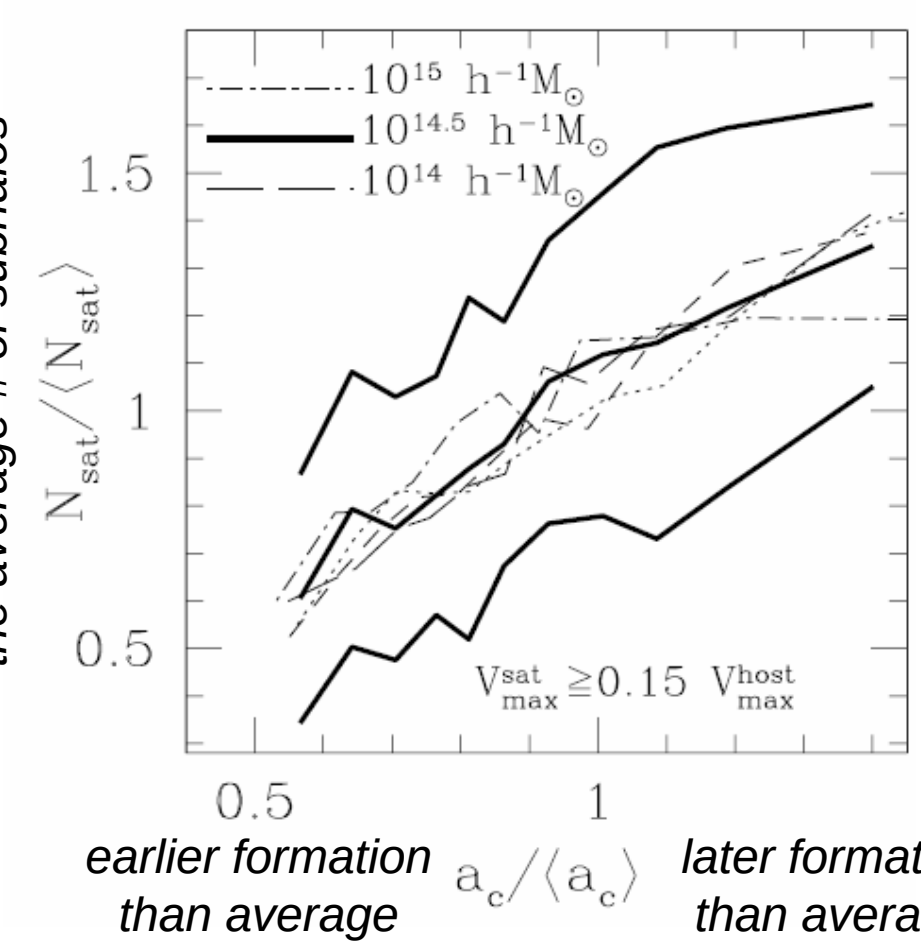
host halos of a given mass

that assemble earlier have on average fewer subhalos
compared to host halos assembling later

Zentner et al. 2005, ApJ 624, 505

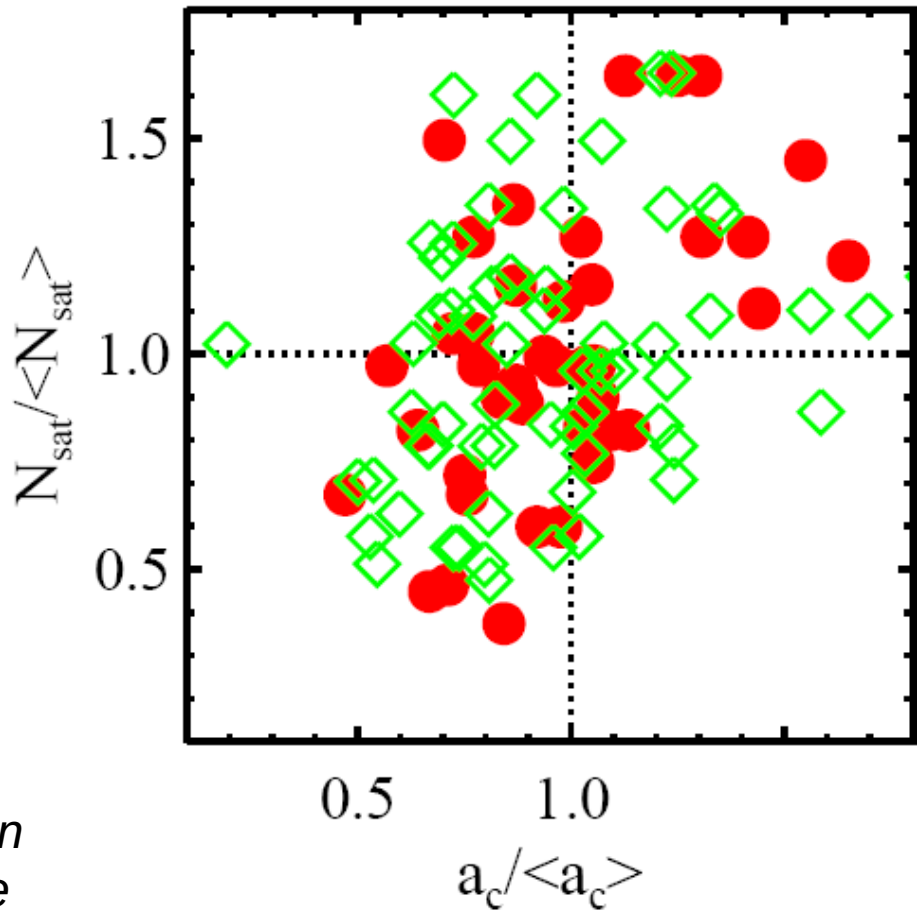
Wechsler et al. 2006, ApJ in press (astro-ph/0512416)

# of subhalos normalized to the average # of subhalos



earlier formation than average

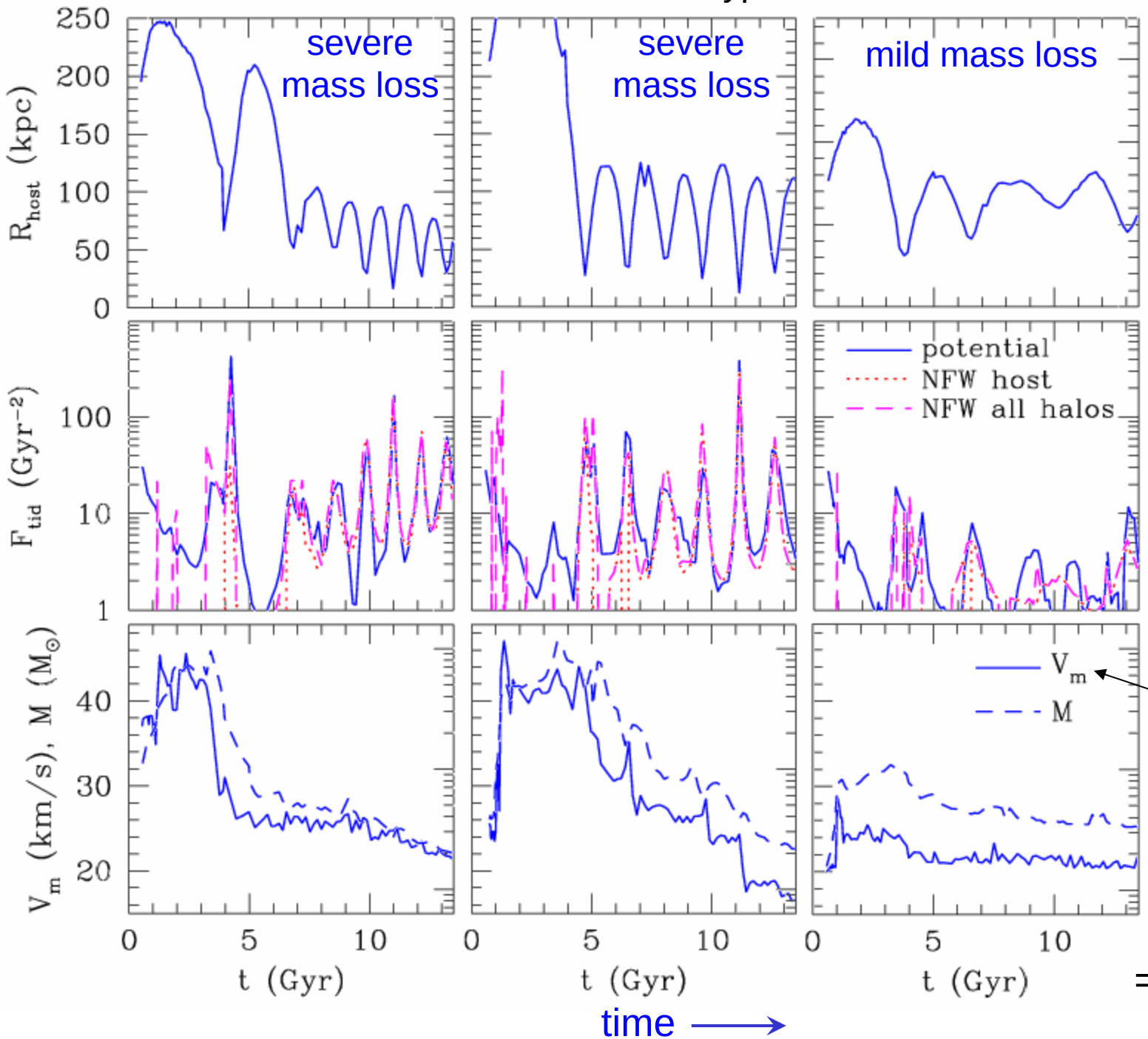
later formation than average



Halo formation epoch (expansion factor) normalized to the average formation epoch of halos of a given mass

Tidal stripping of subhalos: three examples

Kravtsov, Gnedin & Klypin 2004



distance to the host

tidal force

Vmax and grav. bound mass

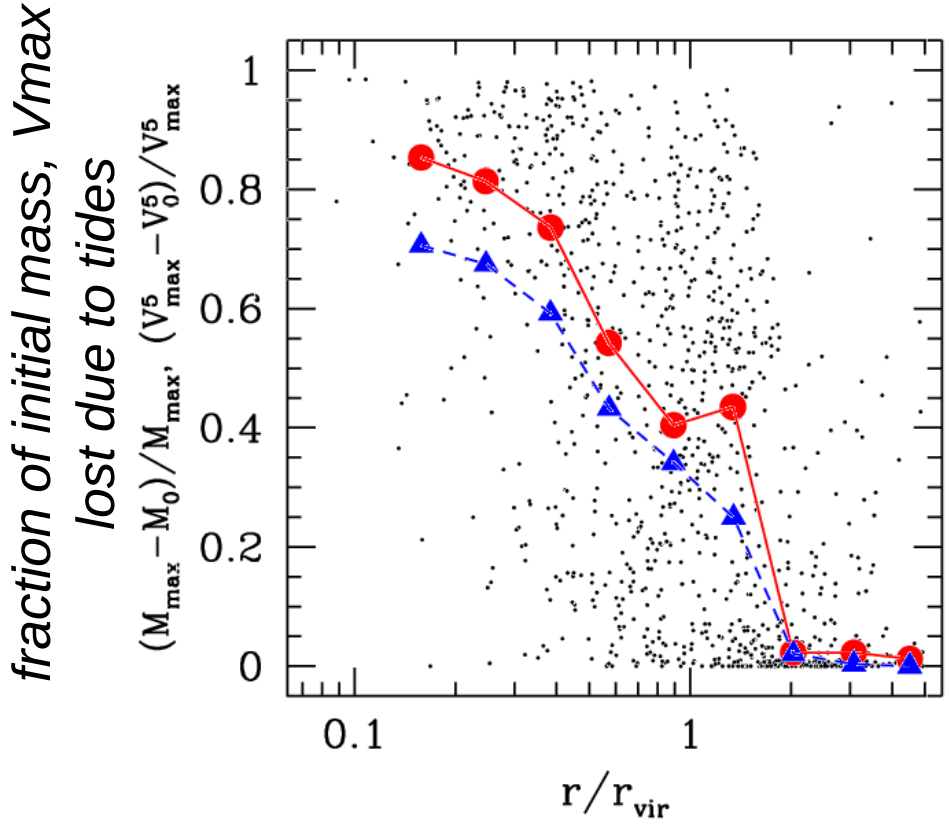
time →

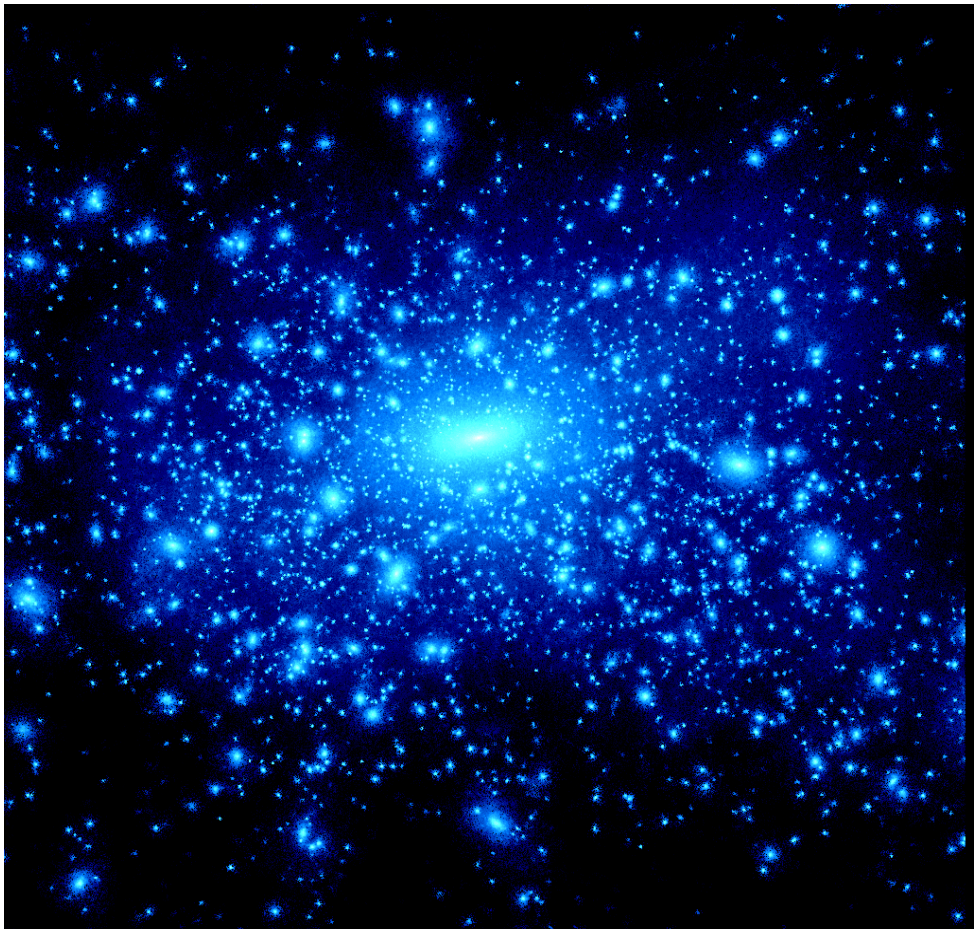
Vm = max of circ velocity curve $=(GM(<r)/r)^{1/2}$

present day subhalo mass and Vmax are affected by tidal stripping

and average effect depends on radius

this introduces a bias in spatial and velocity distributions of subhalos selected using current mass or Vmax





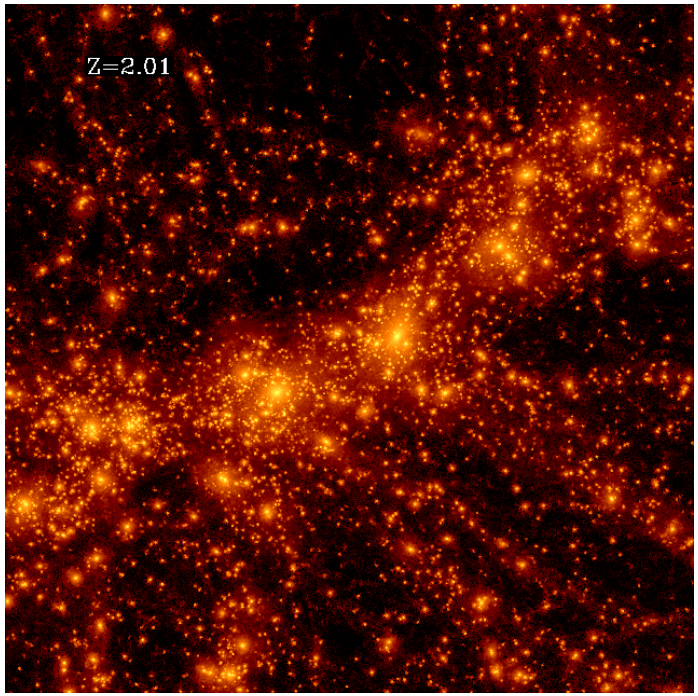
[Nagai & Kravtsov 2005]

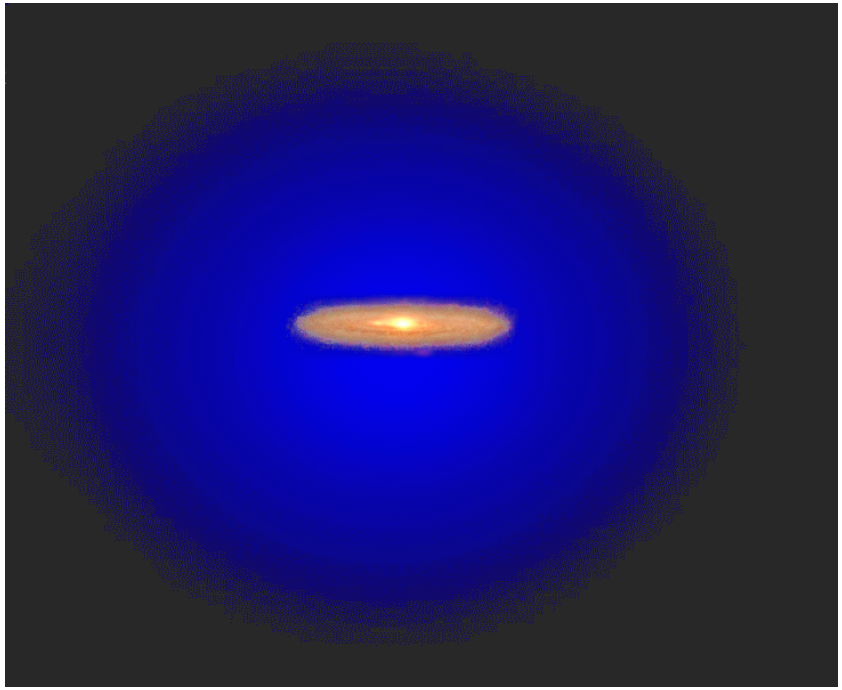
Subhalos = galaxies?

biases are found in spatial and velocity distributions of subhalos. can we expect similar biases for galaxies?

how important are baryons in survival of subhalos?

Ghigna et al. 98, 00; Colin et al. 99, 00; Diemand et al. 04; Gao et al. 04





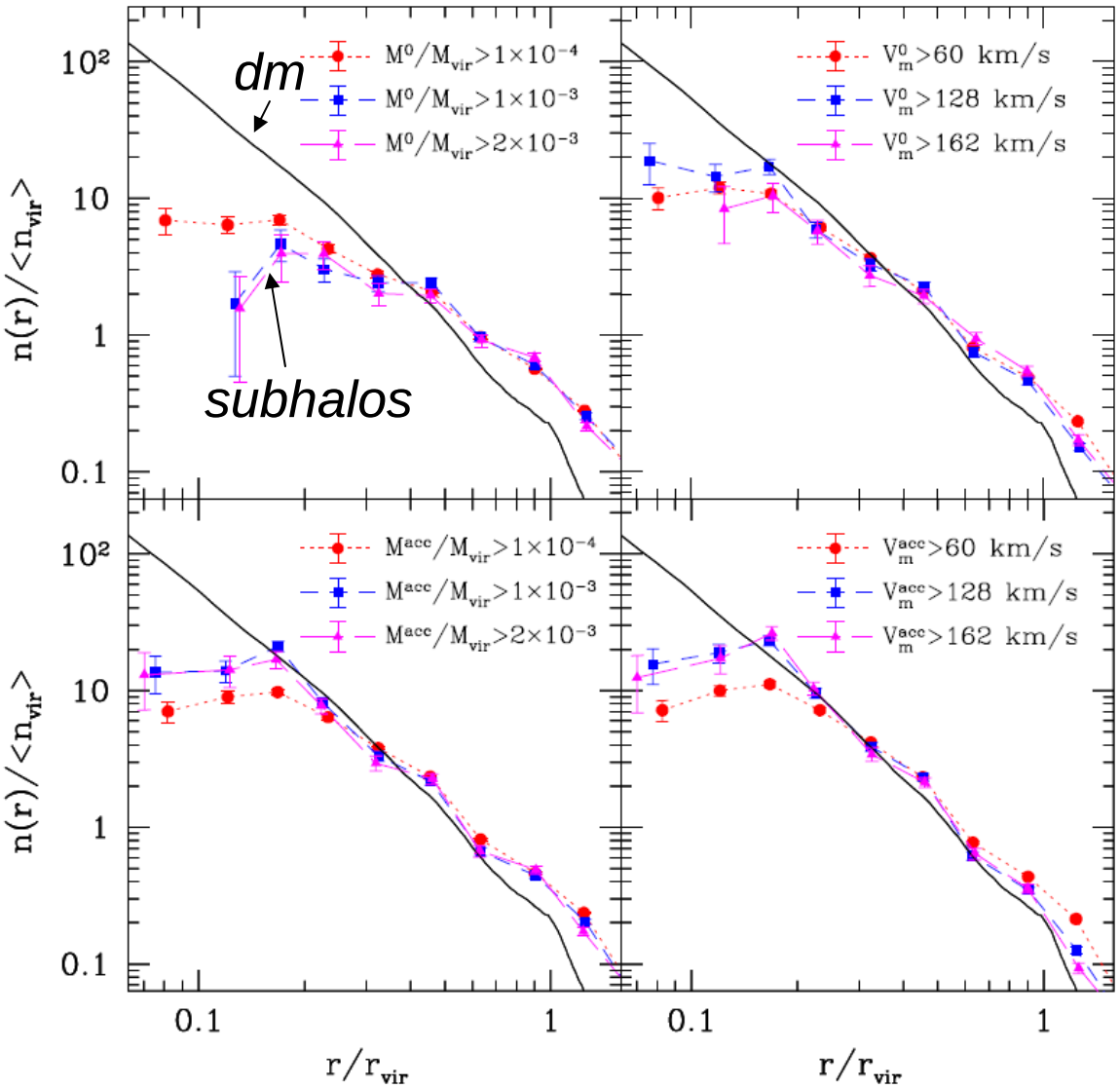
a test – compare radial distribution and abundance of subhalos and galaxies

radial distribution of subhalos depends on how they are selected

radial distribution of subhalos for the same cluster (dissipationless simulation) with different selection of subhalo samples (Nagai & Kravtsov 2005)

subhalos selected using bound mass today

subhalos selected using the mass they had at the accretion epoch



subhalos selected using Vmax today

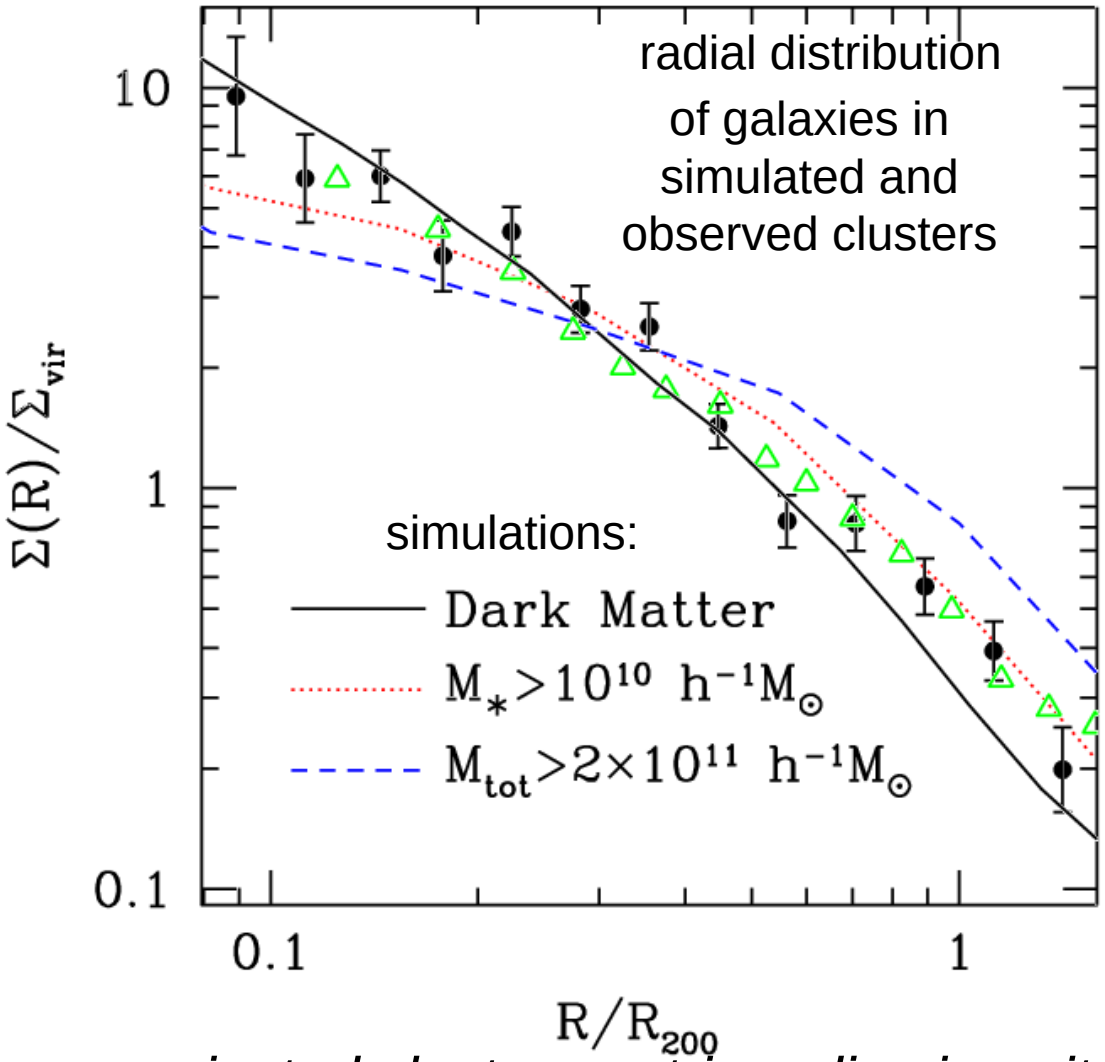
subhalos selected using Vmax they had at the accretion epoch

cluster-centric distance in units of the virial radius

Selection based on a weakly evolving property, such as stellar mass or subhalo mass or Vmax before it is accreted, results in

much reduced spatial and velocity bias

surface density profile



projected cluster-centric radius in units of R_{200}

Nagai & Kravtsov 05;
Faltenbacher et al. 05

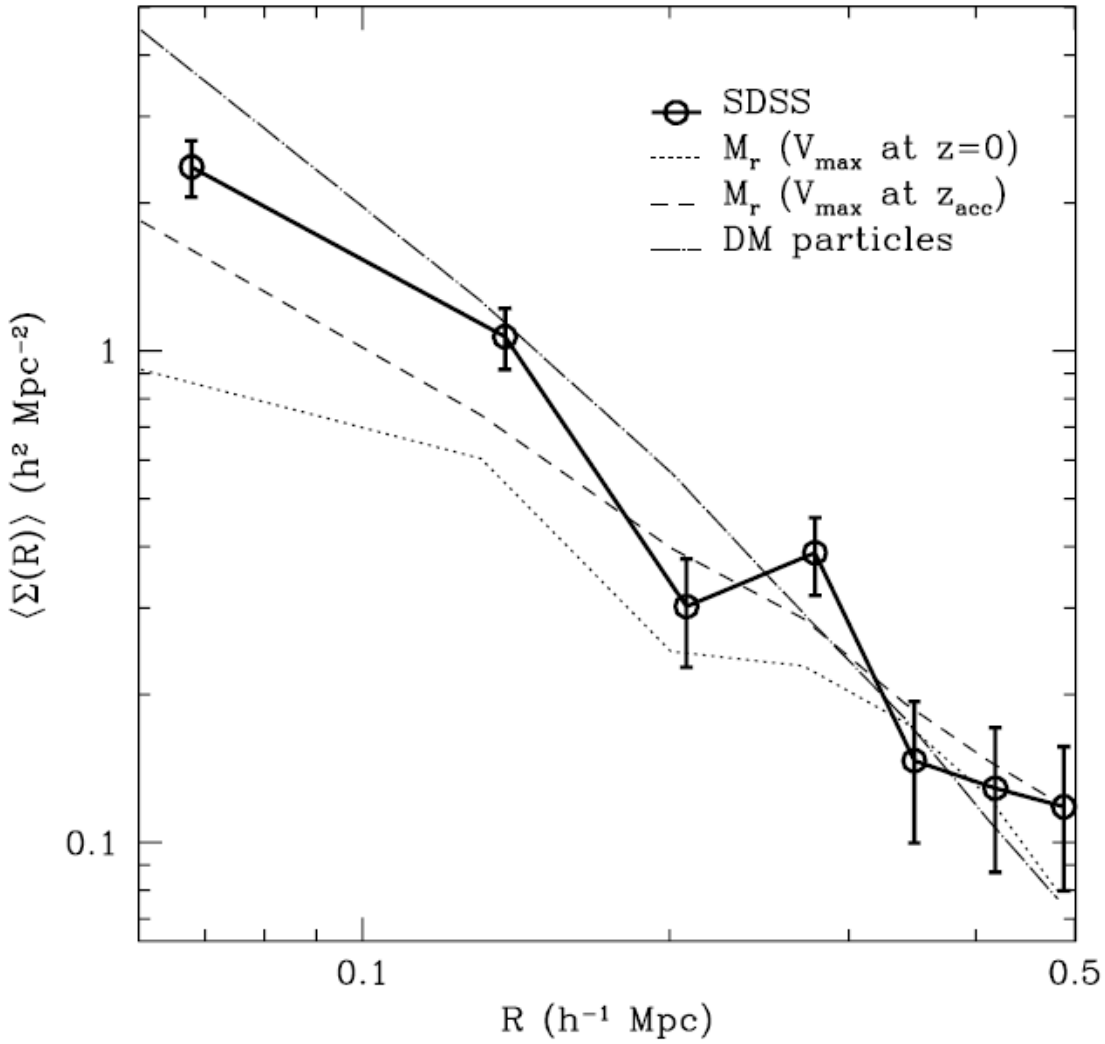
using
hydrodynamic
+ N-body simulations
of clusters
with cooling and
star formation

see also
Faltenbacher &
Diemand 2006
and
Mortonson, Kravtsov &
Nagai 2006

Radial distribution of satellites in galaxy-sized systems

comparison of dissipationless simulations and SDSS measurement

Chen, J. et al. 2006, ApJ 647, 86 (astro-ph/0512376)



Surface density profile

distance to galaxy center

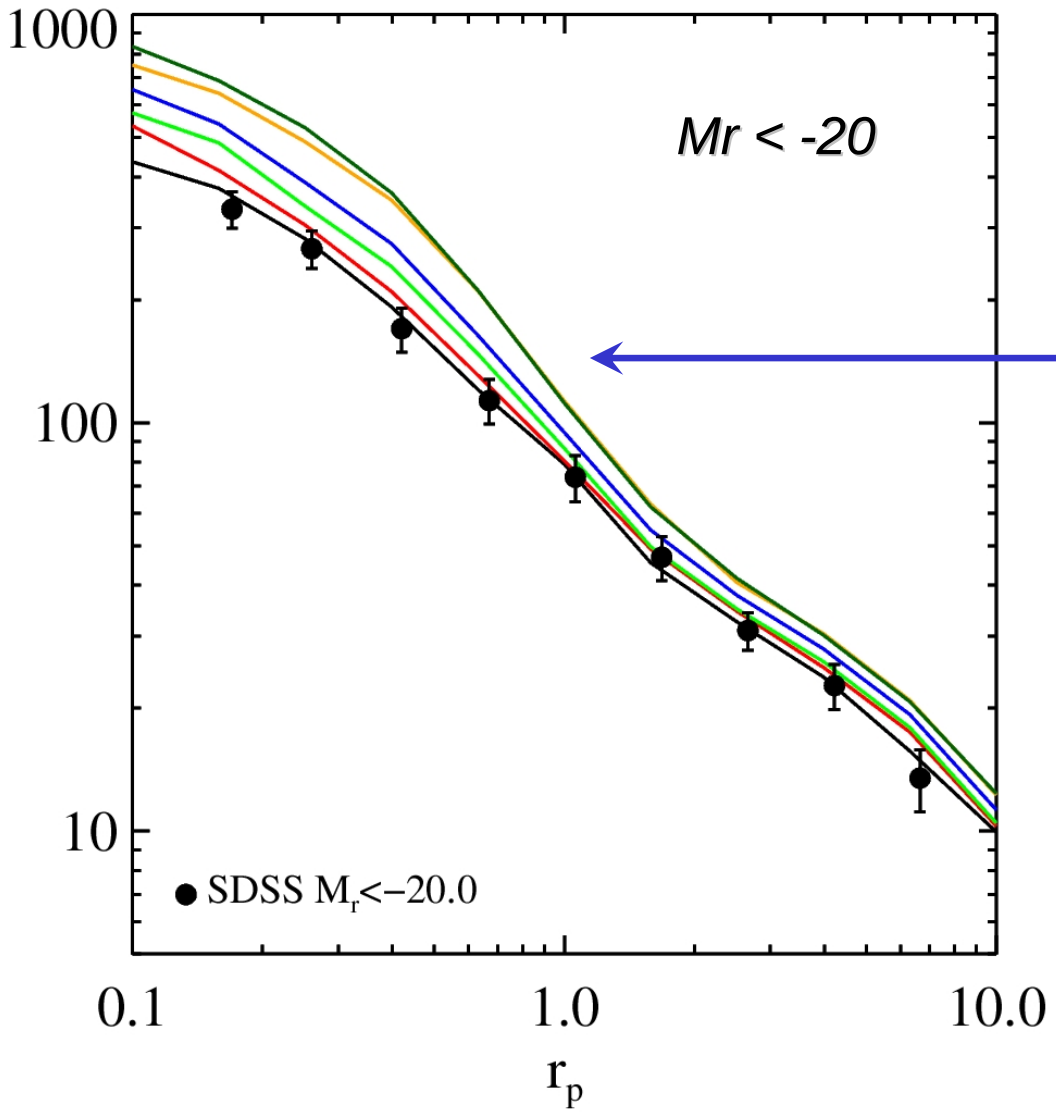
requires careful treatment of interlopers!

Results suggest that galactic satellites have somewhat more extended distribution than the expected distribution of DM

$$n(>V_{\mathrm{max,acc}})=n(>L)$$

Are we missing galaxies in dissipationless simulations?

comparison of observed and predicted halo 2-point correlation functions



projected 2-point correlation function

projected separation (/h Mpc)

$n(>V_{\mathrm{max,acc}})=n(>L)$

assumed fraction of missing galaxies (or orphans) From 10% to 50%

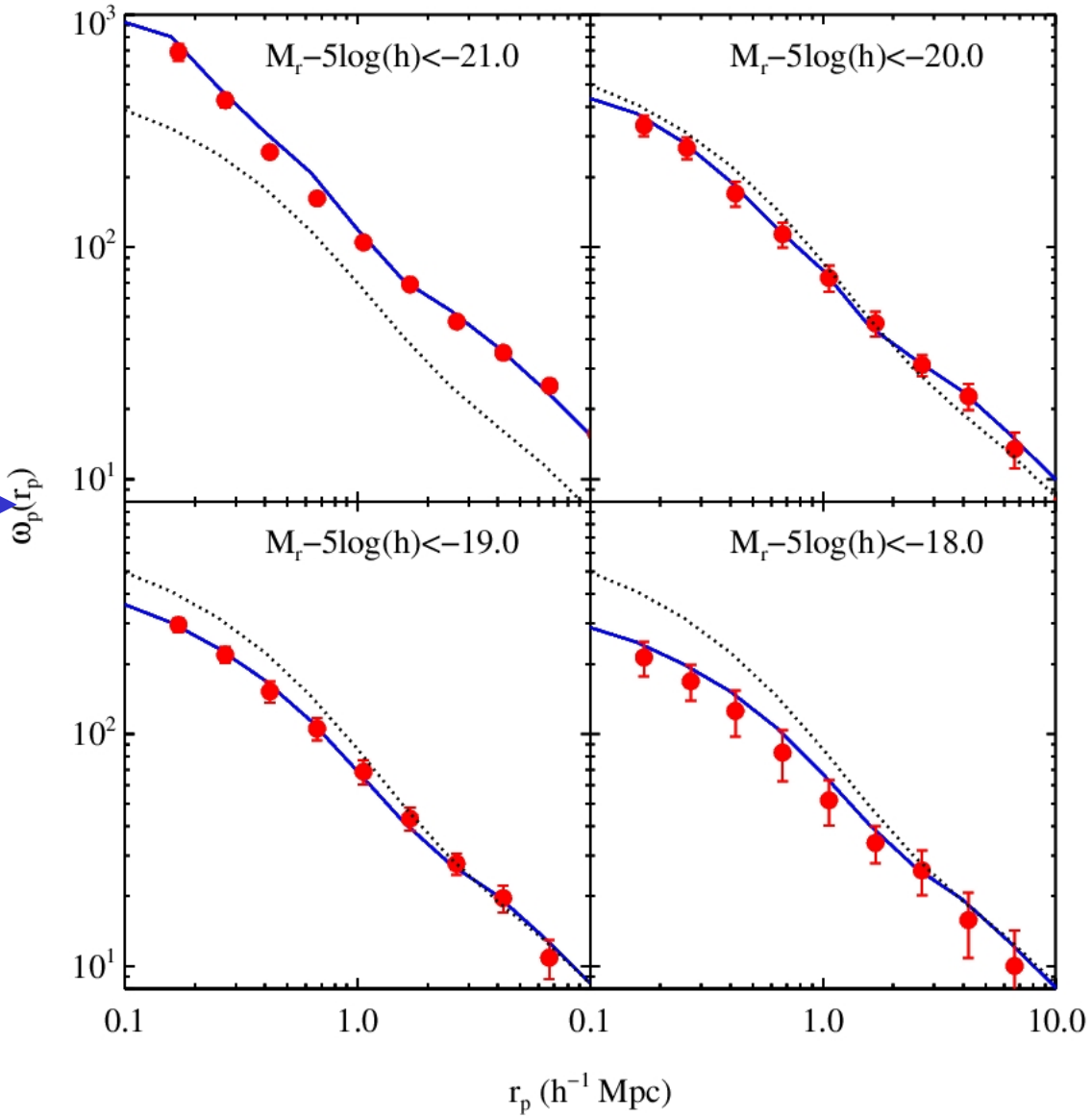
>~20% of additional satellite galaxies would result in CF statistically Inconsistent with the SDSS measurement

-> *subhalos in N-body simulations have approx. correct abundance*

halo clustering vs SDSS

$$w_p(r_p) = 2\int_0^\infty dy\,\xi\left[(r_p^2+y^2)^{1/2}\right]$$

projected 2-point correlation function →



projected separation (chiMpc)

red circles – data

lines – LCDM sim

these are not fits!

halo Vmax
are matched to galaxy
luminosities as

$$n(>V_{\rm max,acc})=n(>L)$$

Conroy,
Wechsler &
Kravtsov
2006, ApJ 647, 201
(astro-ph/0512234)

Summary in pictures