Spatial Distribution and Motions of Galaxies in Clusters

Andrey Kravtsov
Department of Astronomy & Astrophysics
Kavli Institute for Cosmological Physics
The University of Chicago

with
Daisuke Nagai (U.Chicago),
Andreas Faltenbacher (Jerusalem- >UC Santa Cruz)
Stefan Gottloeber (AIP, Potsdam)

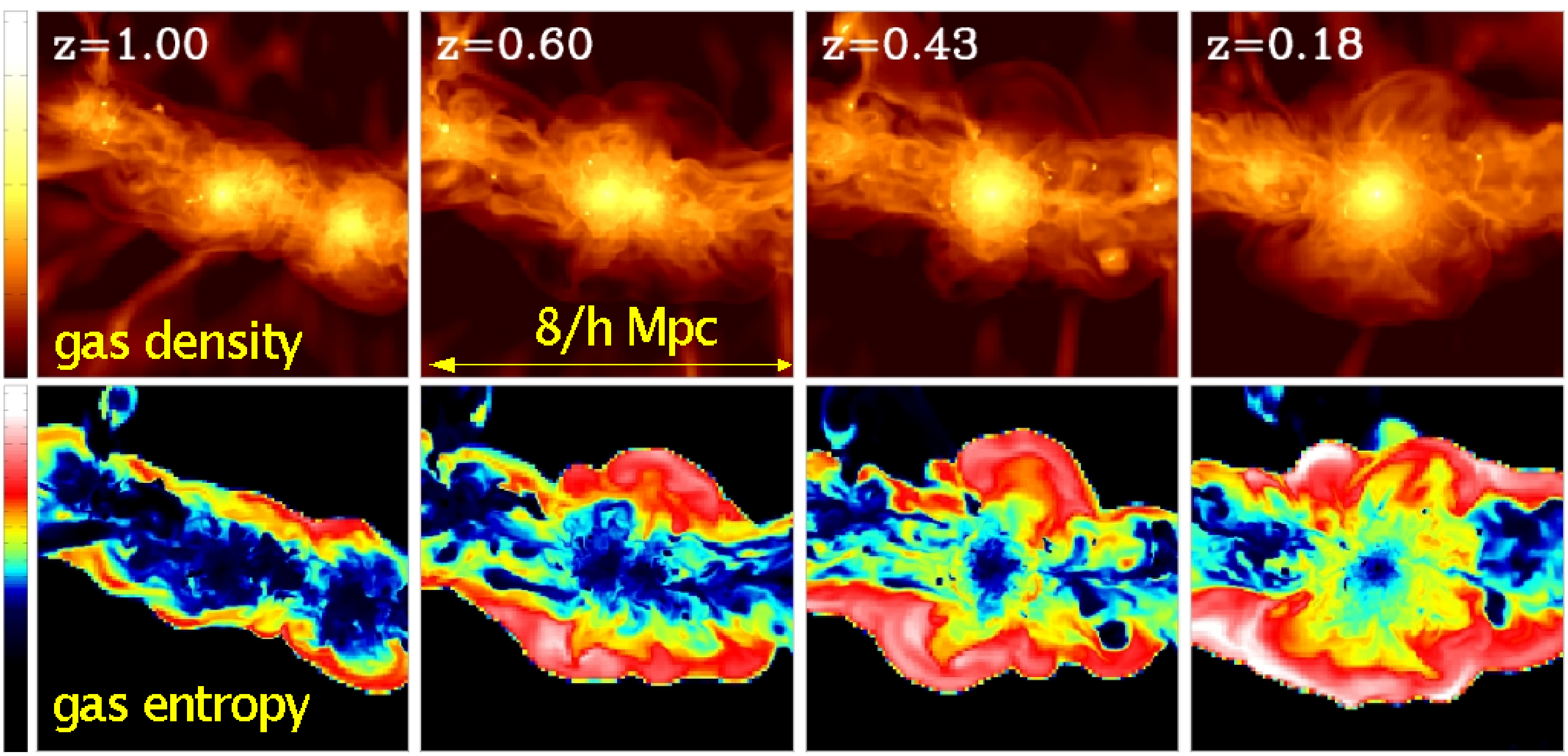
Santa Cruz
5 August, 2004

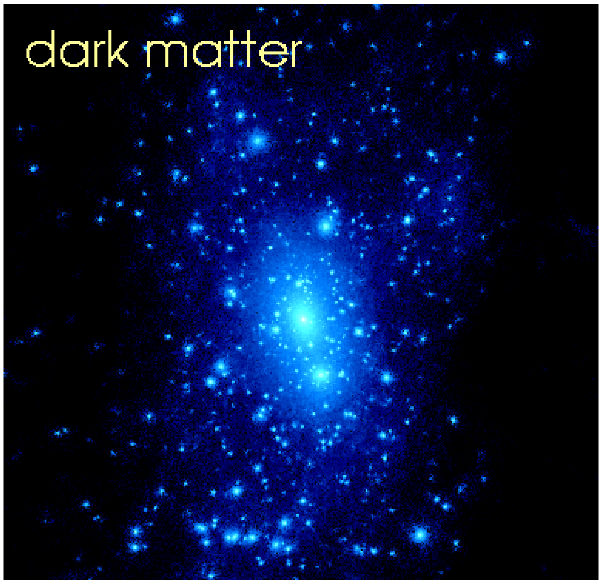
A Sample of 8 Clusters
Formed in the Concordance LCDM Model

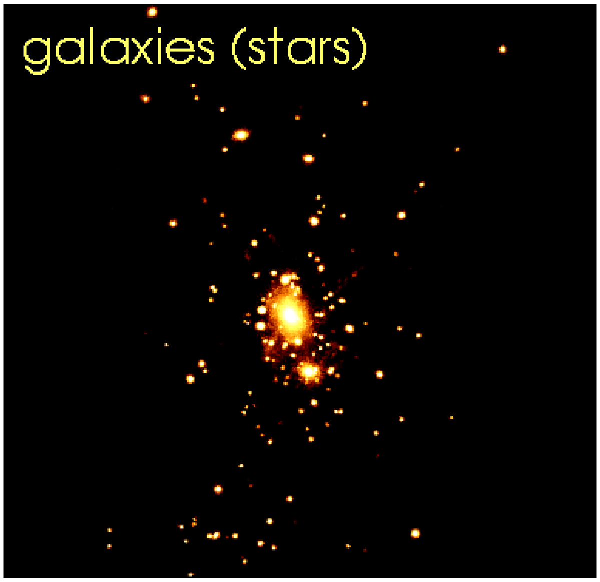
ΛCDM 80h^{-1} Mpc: $\Omega_0 = 0.3$; $\Omega_\Lambda = 0.7$; $h = 0.7$; $\sigma_8 = 0.9$; $n_s = 1.0$

m_{DM}=3 x10^8 h^{-1} Msun; ε peak= 2h^{-1} kpc

Mvir ~ 0.5 - 3 x10^{14} h^{-1}Msun







The physical processes included in simulations:

Gasdynamics: Eulerian AMR Adaptive Refinement Tree (ART) code

Collisionless N- body dynamics of DM and stars

Radiative cooling and heating of gas: metallicity dependent net cooling/heating equilibrium rates tabulated for $100 < T < 10^9$ K

Star formation using observationally- motivated phenomenological recipe (Kennicutt 1998)

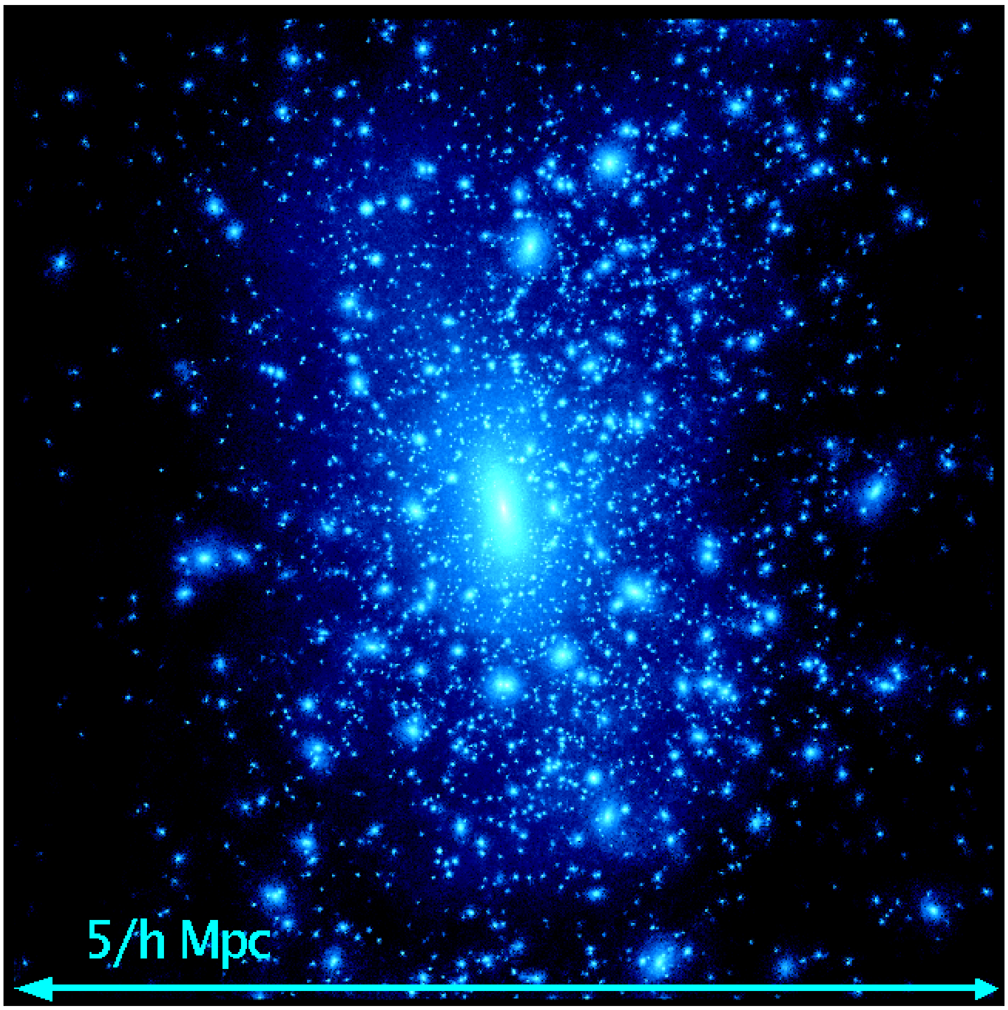
Thermal stellar feedback

Metal enrichment by SNII/Ia,

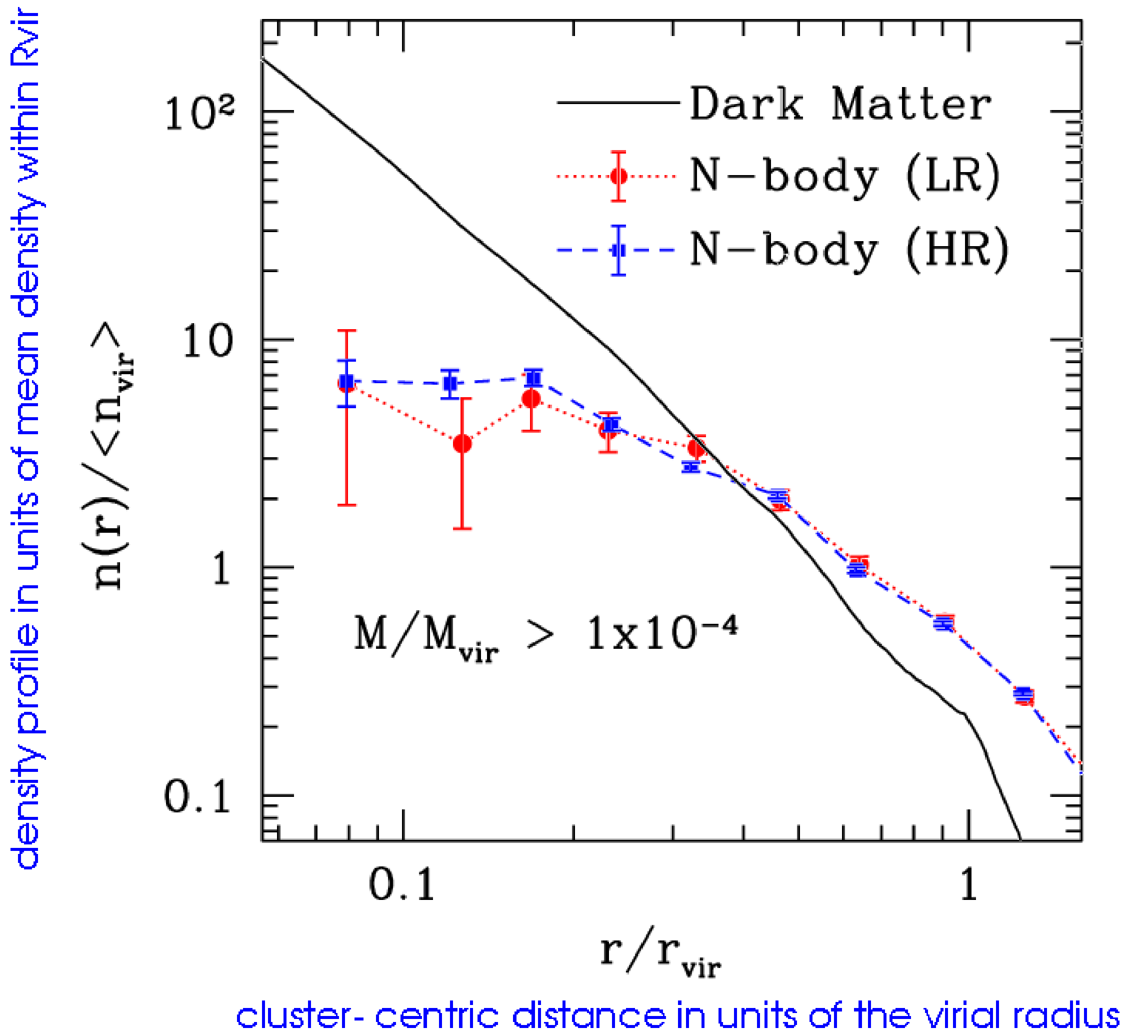
Advection of metals

Stellar mass loss based on population synthesis models

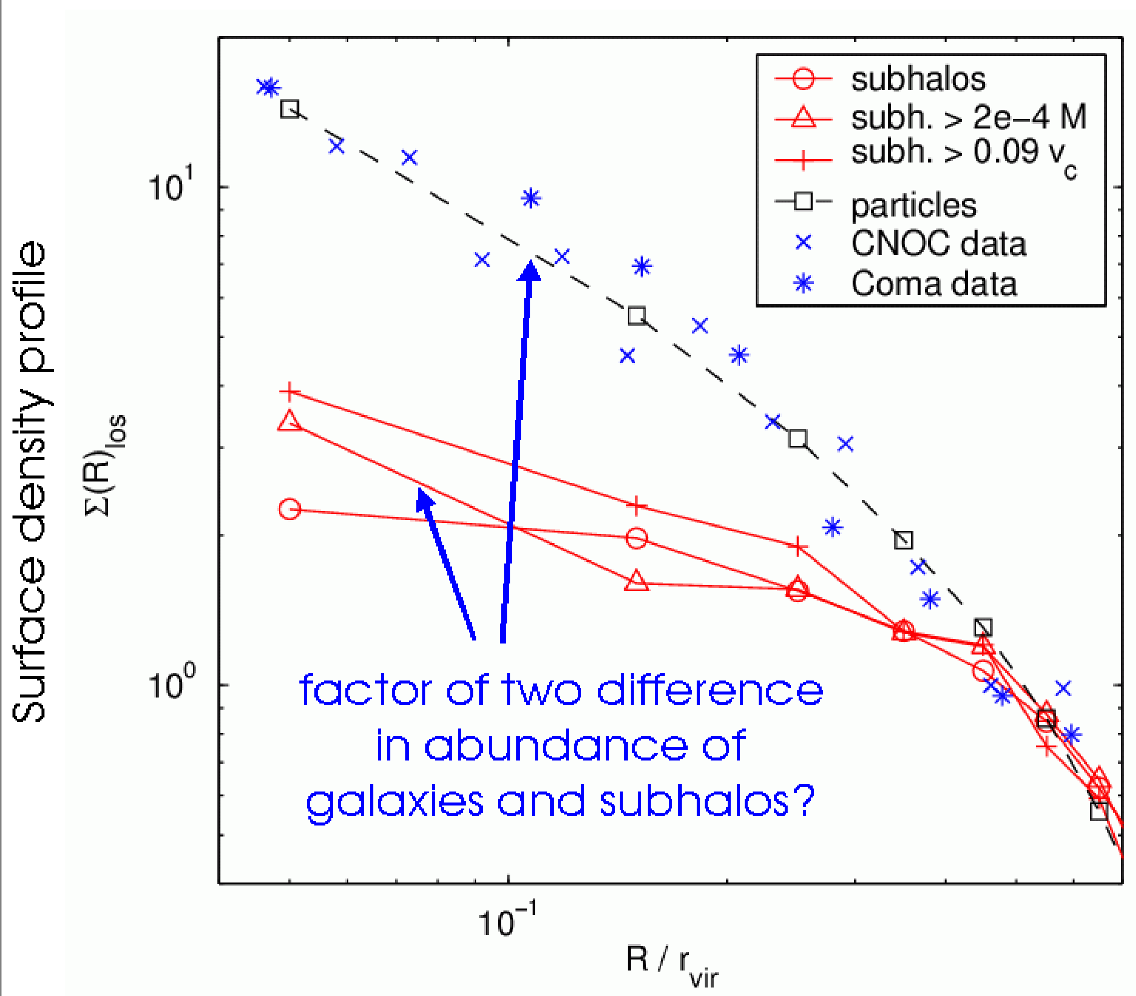
High- resolution dark matter only resimulation of one of the clusters



Number density profile of subhalos vs DM profile



Radial distribution of subhalos in dissipationless simulations does not match observations



Diemand, Moore & Stadel 2004

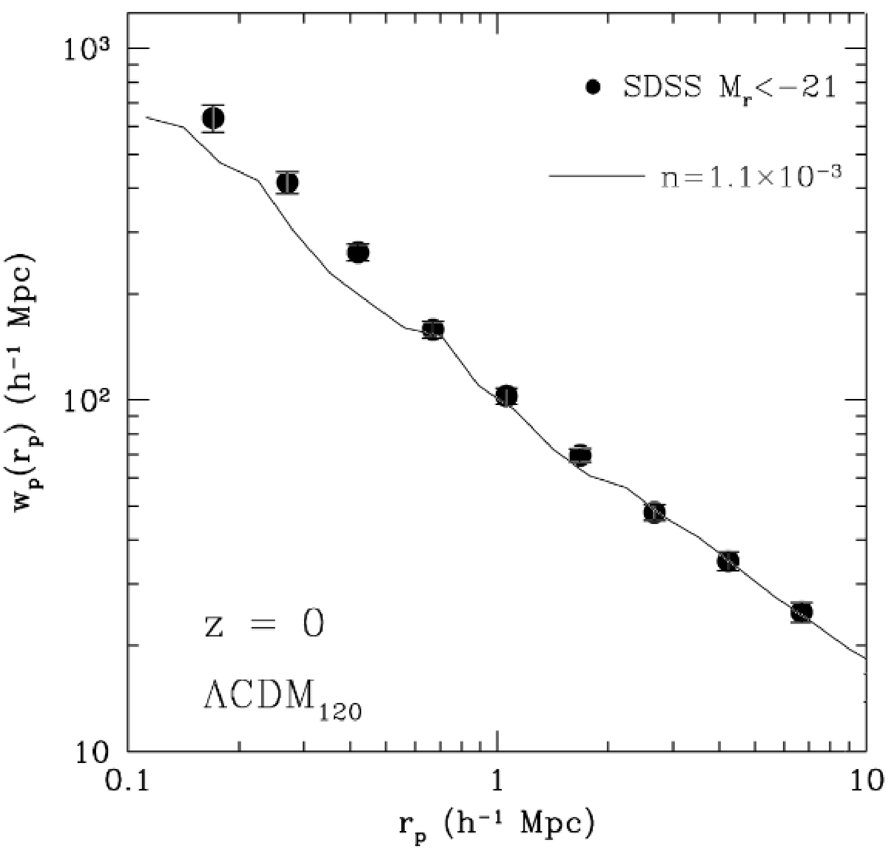
Gao et al. 2004

projected cluster- centric radius in units of the virial radius

2- point correlation function of galactic halos dissipationless simulation vs SDSS

$$n_h(>Vmax) = n_g(>Lr)$$

projected correlation function



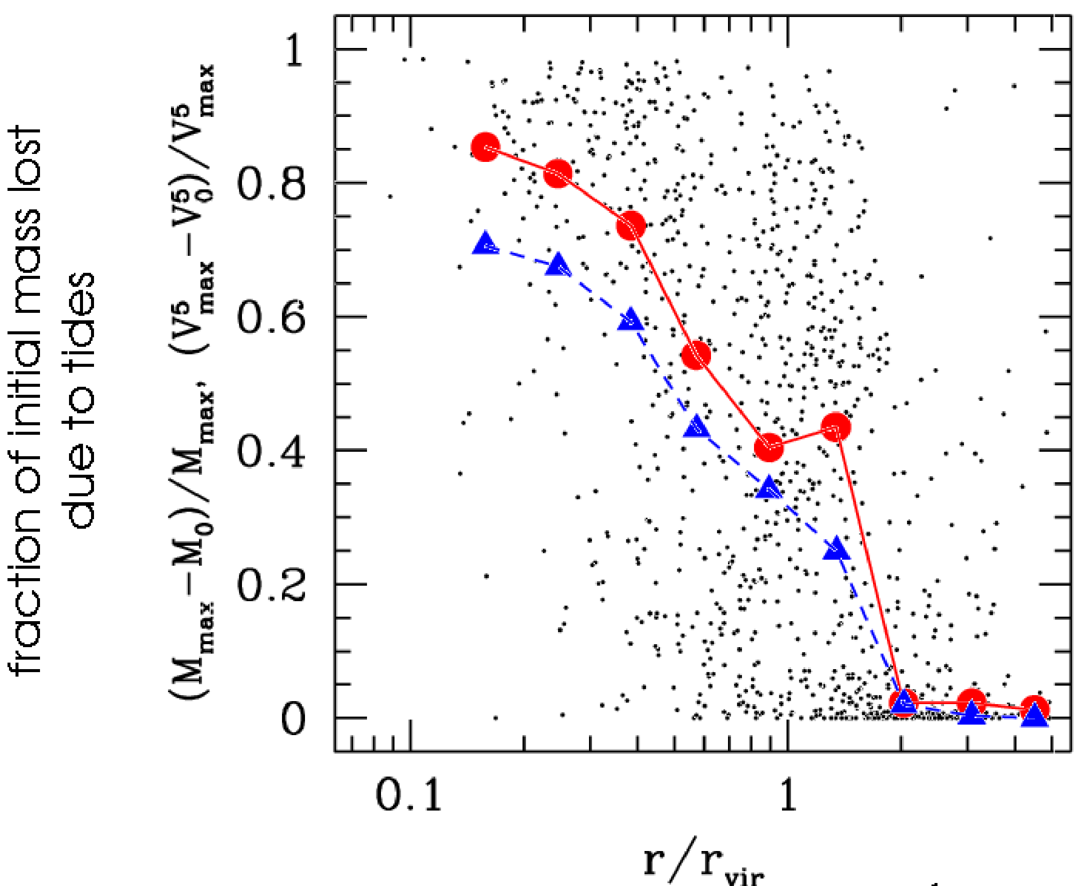
projected distance

SDSS CF:
Zehavi et al. 2003

Simulation CF:
Kravtsov et al. 2004

See also
Colin et al. 1999
Kravtsov & Klypin 1999

Tidal mass loss introduces a strong radial bias for subhalo samples selected using bound mass

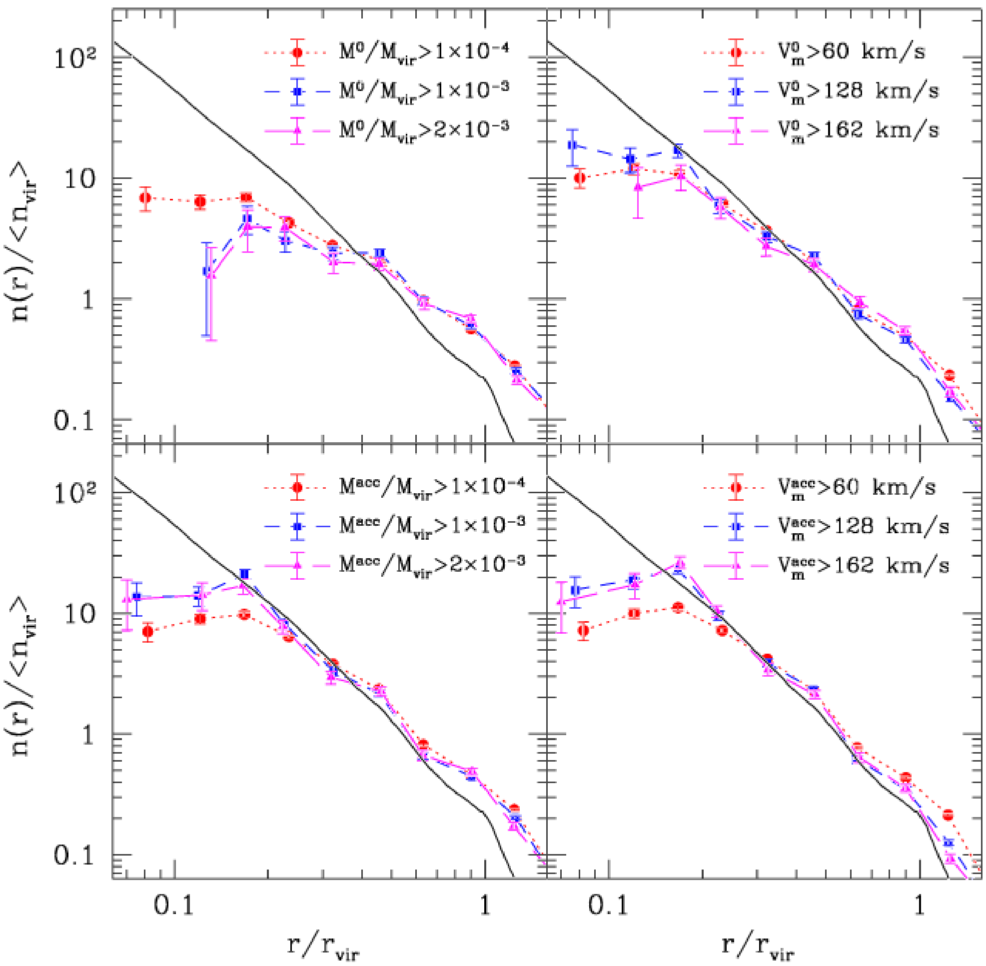


(Nagai & Kravtsov 2004)

Subhalo number density profile depends on how the subhalos are selected!

subhalos selected using bound mass today

subhalos selected using Vmax today

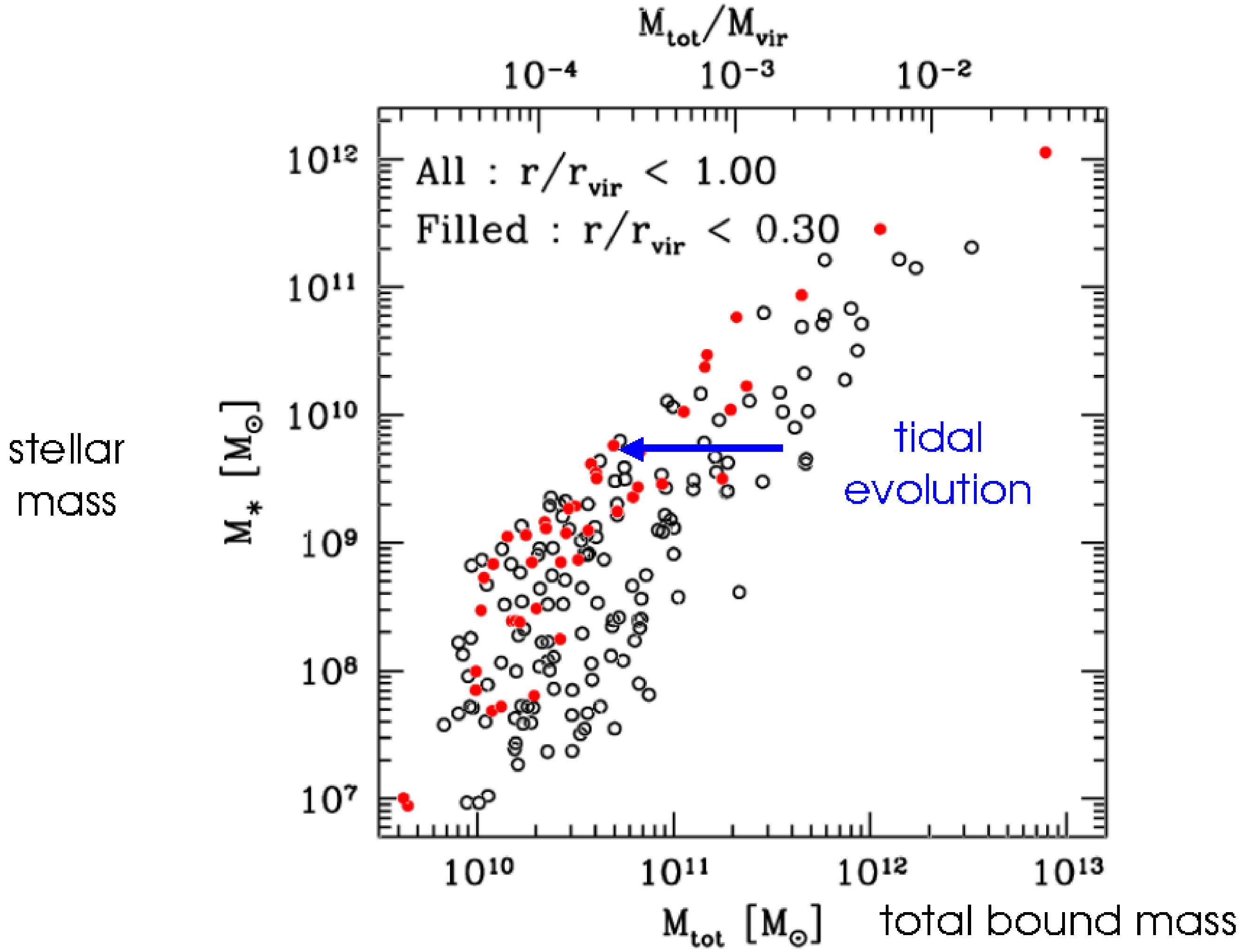


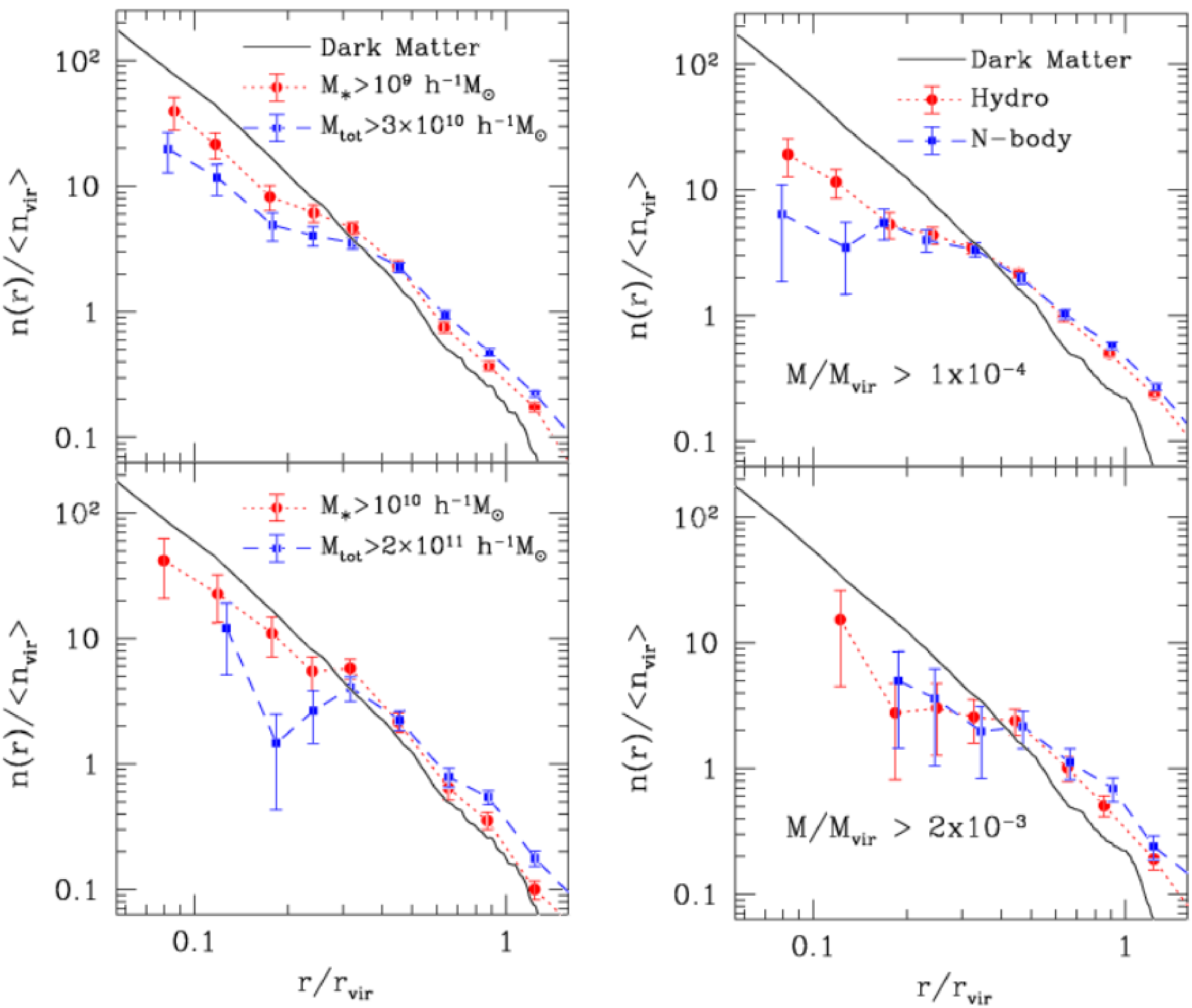
subhalos selected using the mass they had at the accretion epoch

subhalos selected using Vmax they had at the accretion epoch

cluster- centric distance in units of the virial radius

Stellar mass is preserved much better than the total bound mass

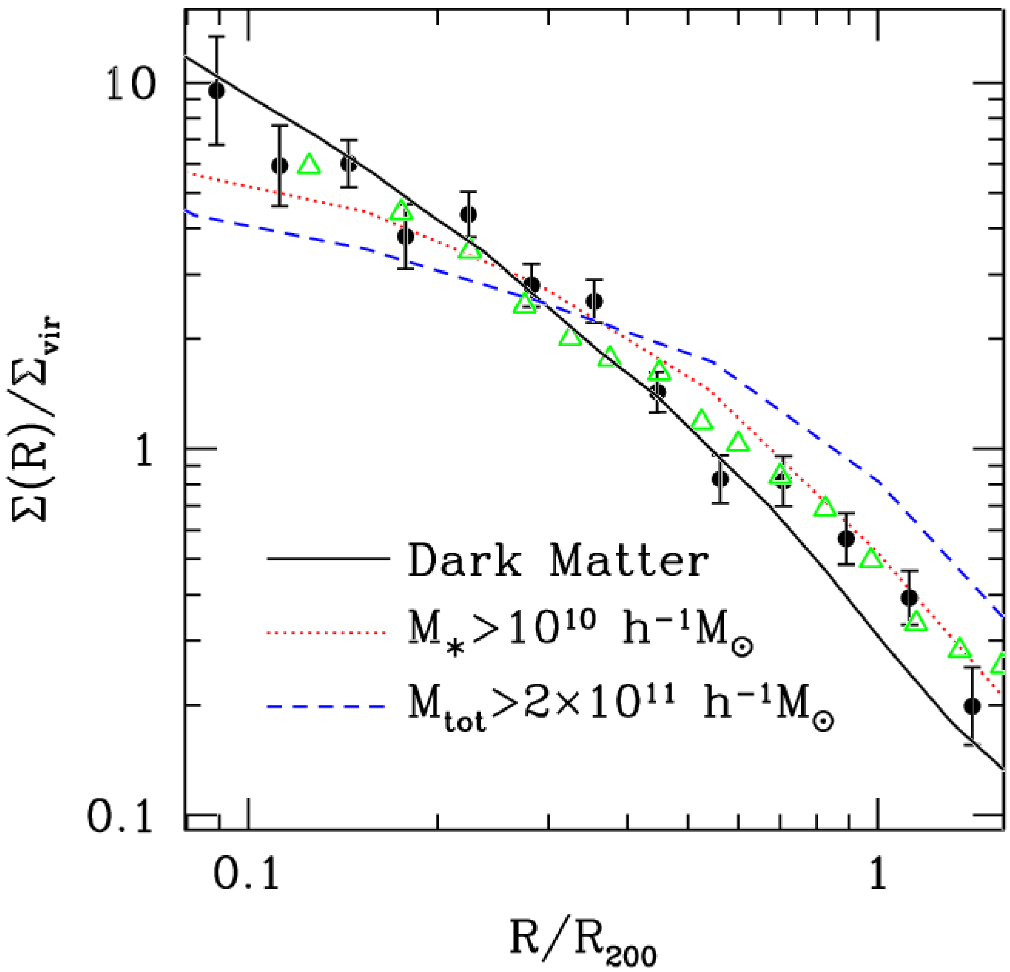




Dark Matter
$M_*>10^9\ h^{-1}M_\odot$
$M_{tot}>3\times10^{10}\ h^{-1}M_\odot$
$M_*>10^{10}\ h^{-1}M_\odot$
$M_{tot}>2\times10^{11}\ h^{-1}M_\odot$
Hydro
N-body
$M/M_{vir} > 1\times10^{-4}$
$M/M_{vir} > 2\times10^{-3}$
$n(r)/<n_{vir}>$
r/r_{vir}

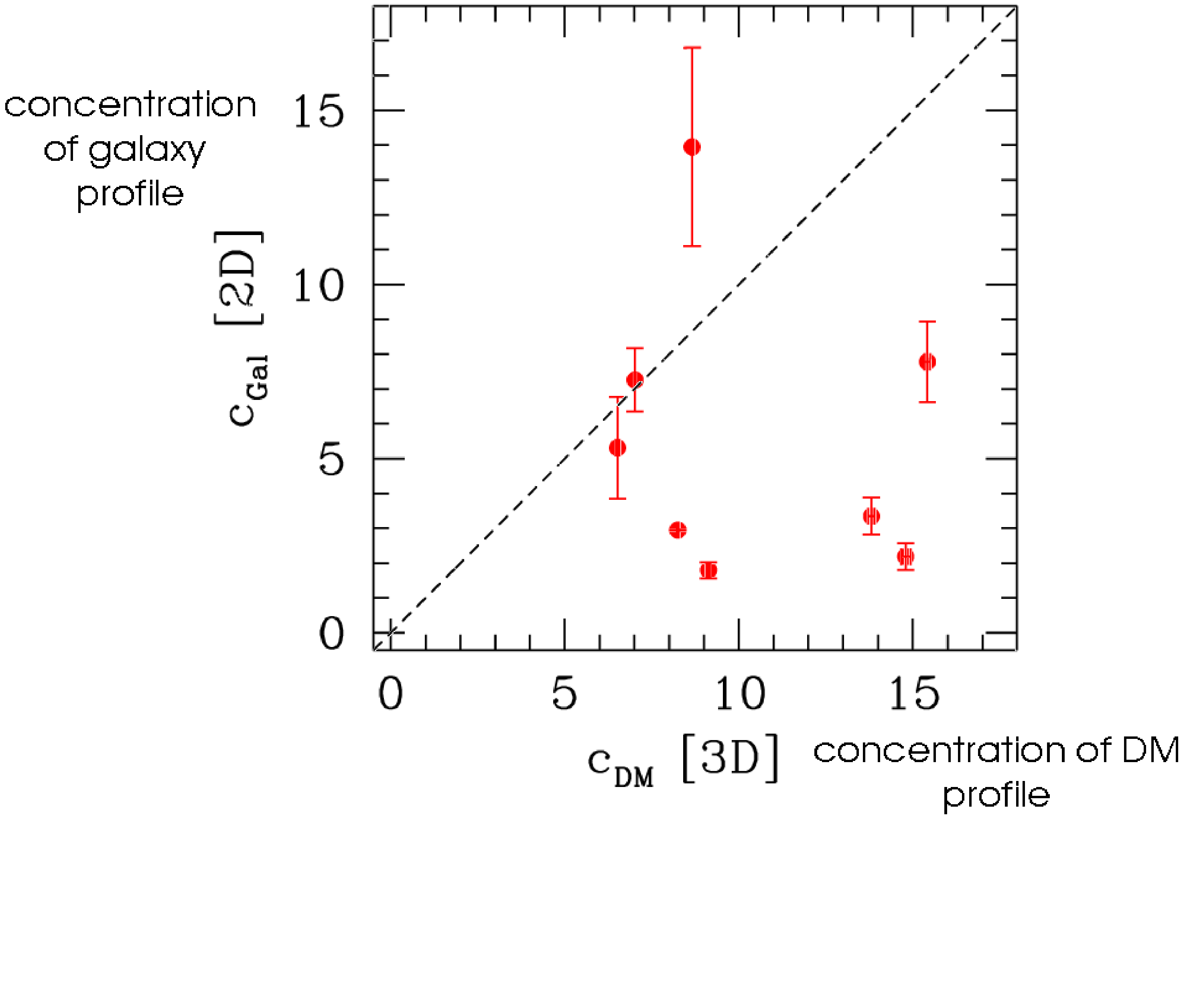
Comparison to observations

surface density profile



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

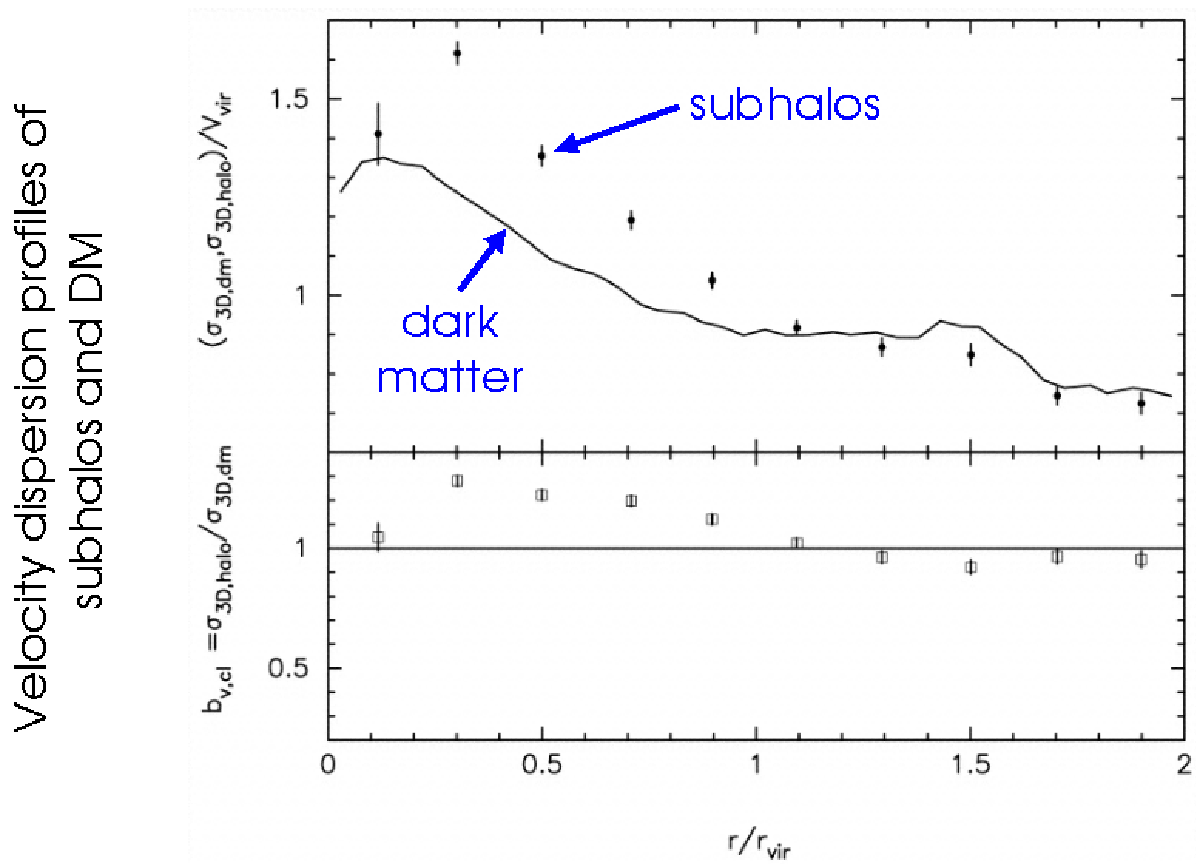
Concentration parameter of galaxy profiles vs concentration of the cluster DM profile



Velocity bias of subhalos

$b_v \sim 1.3$ at $r \sim 0.5 r_{vir}$

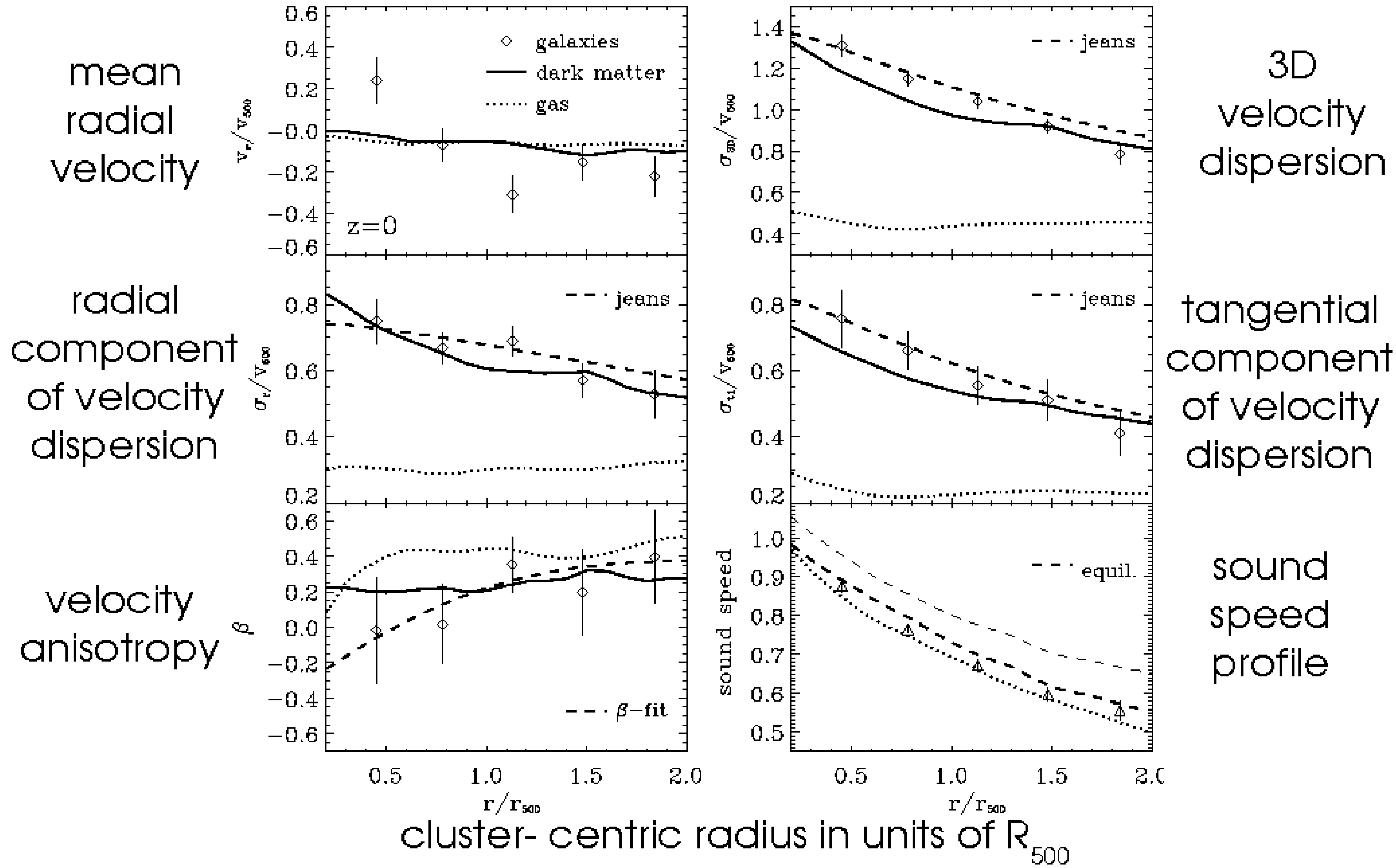
Colin et al. 2000; Ghigna et al. 2000; Diemand et al. 2004; Gao et al 2004



projected cluster- centric radius in units of the virial radius

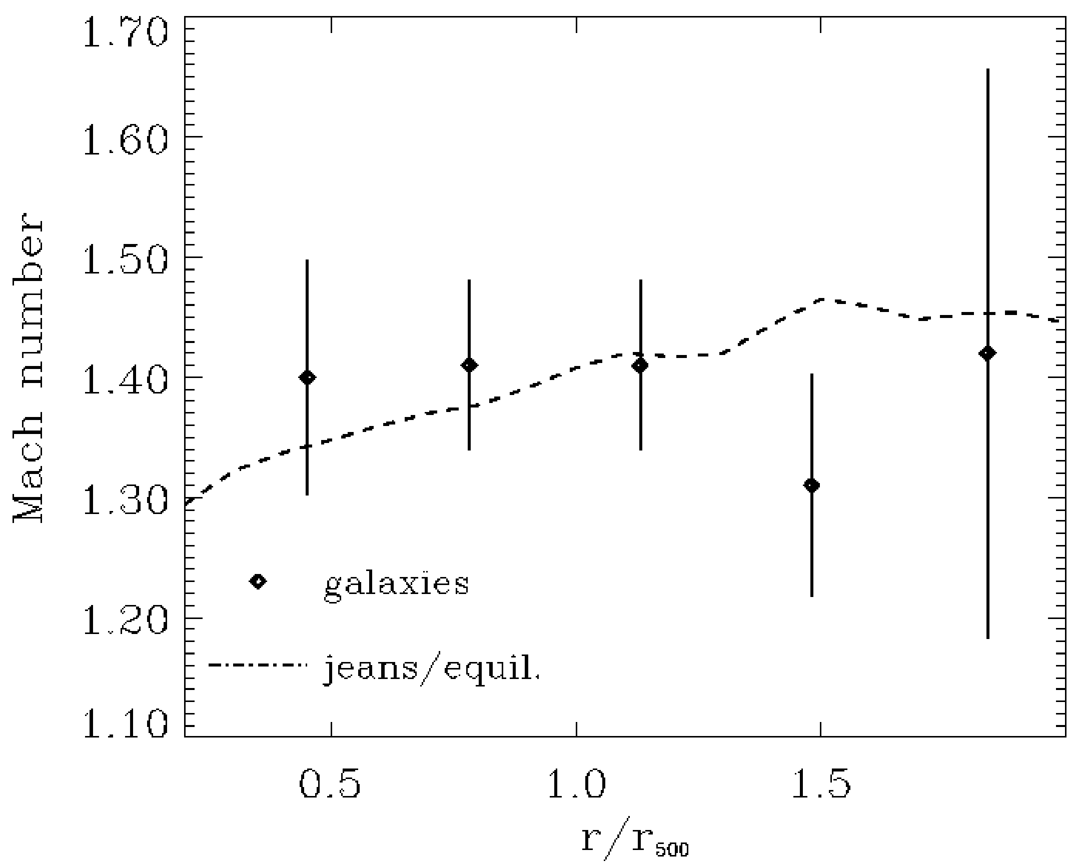
Statistics of galaxy motions in simulated clusters

note the galaxy velocity bias, b_v~1.1- smaller than for subhalos in dissipationless simulations



On average, galaxies in clusters move with Mach~1.4

average Mach number of galaxy motions



cluster- centric radius in units of R_{500}

(Faltenbacher et al. 2004)

Summary

❑ Radial distribution of subhalos in clusters depends sensitively on how the subhalos are selected.

Comparisons with observations are tricky!

❑ Radial distribution of galaxies in LCDM clusters is in good agreement with observations

❑ Velocity bias of galaxies is smaller (b_v~1.1) than the velocity bias of subhalos selected by mass or Vmax

❑ On average, galaxies in simulated clusters move supersonically with the average Mach number of ~1.4

--> *Interesting implications for evolution of cluster galaxies and heating of the intracluster medium*

for details see (to appear on astro-ph in the next two weeks):
Nagai & Kravtsov 2004; Faltenbacher, Kravtsov, Nagai & Gottloeber 2004