

# Impact of tidal forces on subhalo distributions

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## What is meant by bias ?

- **Subhalos**  
CDM simulation of a galaxy cluster = host halo  
the surviving bound substructures = subhalos
- **Spatial bias**  
differences in the number density profiles of  
a subhalo sample compared to the overall  
density distribution
- **Velocity bias**  
differences in the velocity dispersion profile of  
a subhalo sample compared to the overall  
velocity dispersion profile

## Spatial bias: How to associate subhalos with galaxies?

- Overmerging, a problem related to resolution  
White (1976), van Kampen (1995)
- Abundance of CDM structure seems to match  
galaxy abundance in clusters (but not L.G. satellites)  
Moore et al. (1999)
- Are the subhalos too far from the center ?  
Diemand (2004)
- Improvement by selection of subhalos according to  
mass (or circular velocity) before accretion:  
Nagai & Kravtsov (2005), Conroy et al. (2006)

## Velocity bias: How does it affect mass measurements?

- Subhalos (selected by current mass) are hotter than the diffuse CDM component  
e.g. Colin et al. (2000)
- The velocity bias in semianalytical galaxy cluster models is substantially reduced  
Gao et al. (2004)
- High resolution simulation with **simple** subhalo/galaxy selection criteria to investigate velocity distributions of galaxy clusters

## CDM simulation of a galaxy cluster

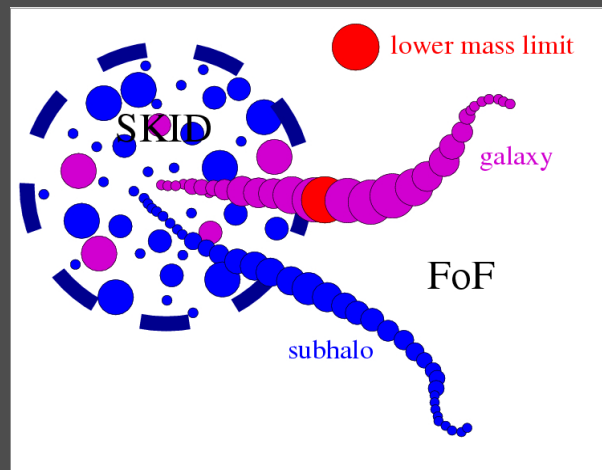


Diemand et al. (2004)

- $3.1 \times 10^{14} M_{\odot}$  host halo (at  $z = 0$ )
- $14 \times 10^6$  particles
- $2.2 \times 10^7 M_{\odot}$  per particle
- 1.8 kpc softening length

## subhalos and galaxy halos

- Lower mass limit applied at **at  $z=0$**   
10 particles ( $2.2 \times 10^8 M_{\odot}$ )
- Lower mass limit applied when **entering  $R_{vir}$**   
200 particles ( $4.4 \times 10^9 M_{\odot}$ )

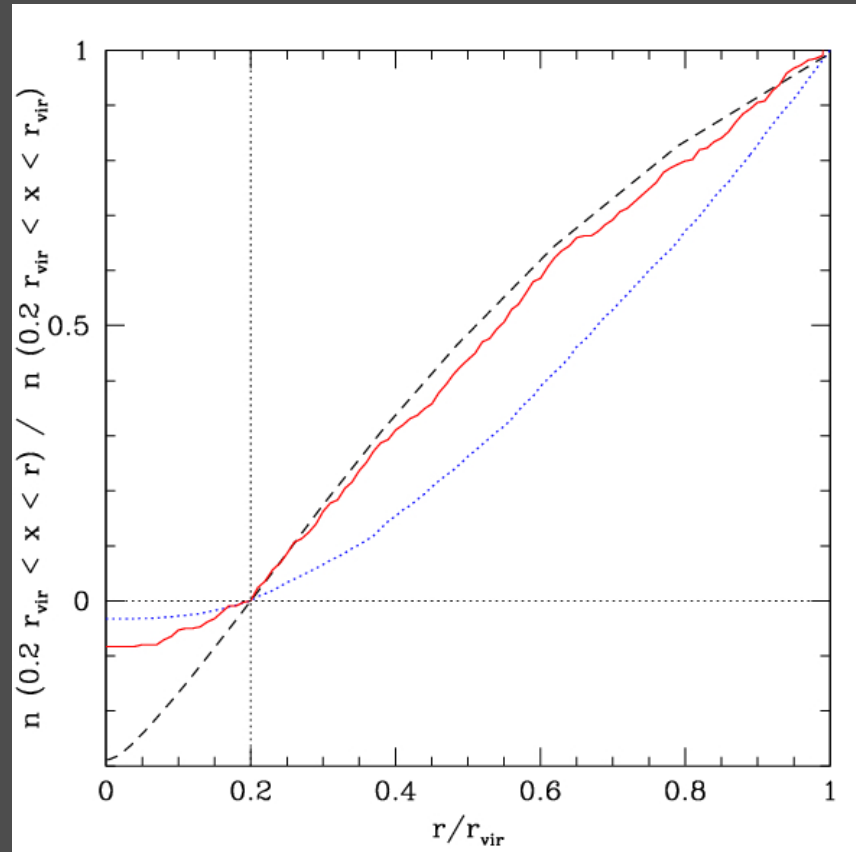


further on: **galaxy halo sample** , **subhalo sample**



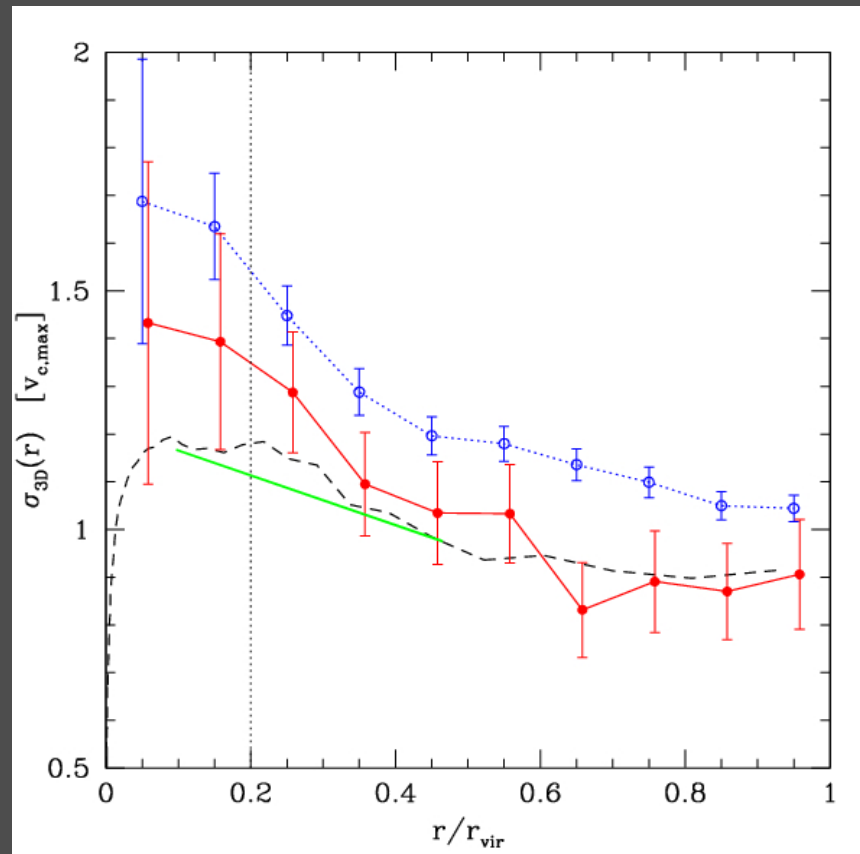


## Spatial biases



galaxies (solid), subhalos (dotted), dark matter (dashed)

## Velocity biases



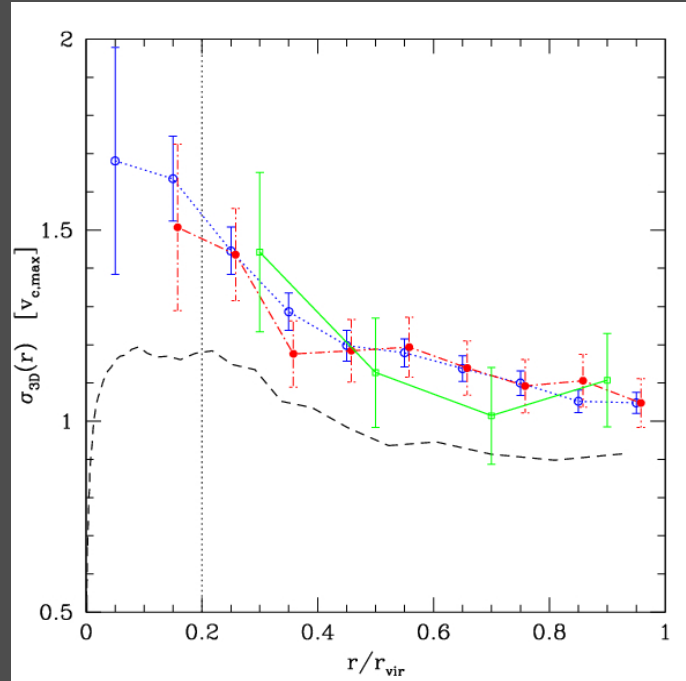
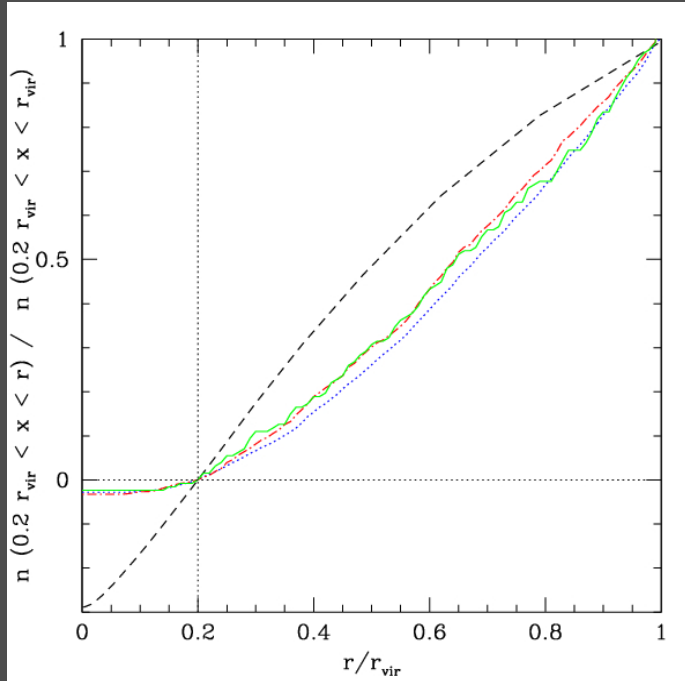
galaxies (solid), subhalos (dotted), dark matter (dashed)

Is dynamical friction responsible for **subhalo** biases?

$$\left(\frac{du}{dt}\right)_{df} \propto -\rho m u^{-2} \left[ \text{erf}(X) - \frac{2}{\pi^{1/2}} X e^{-X^2} \right]$$

$$X = u/(\sqrt{2}\sigma)$$

## Higher mass limits for **subhalo** sample



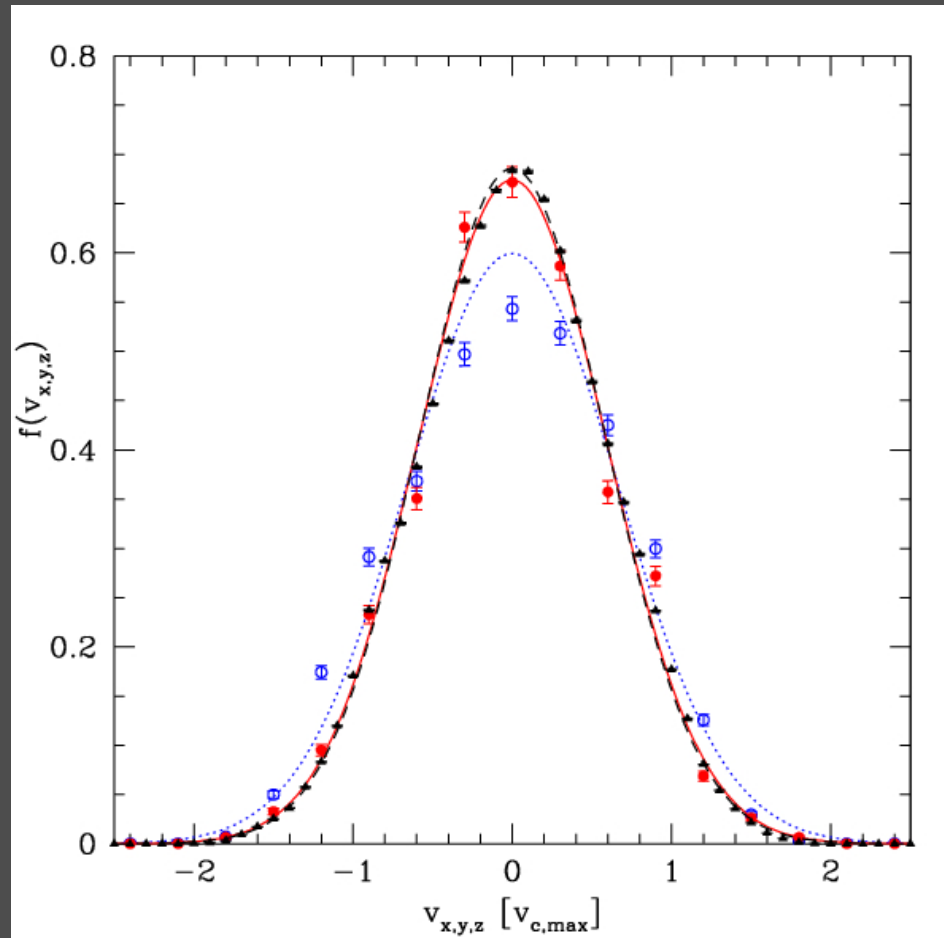
minimum number of particles: **10**, **100**, **1000**  
minimum number of objects in a bin: 16

**no mass dependence**

## Is tidal destruction responsible for **subhalo** biases?

- the mass function of subhalos is steep  $\propto -2$   
e.g. Reed et al. (2005)
- subhalos suffer substantial mass loss due to tidal stripping
- applying a lower mass limit (10 particles) results in a **young**, i.e. **more recently accreted** sample
- whereas the selection of the **galaxy halos** results in a **long-lived** sample
- dark matter particles are by definition long-lived

# Velocity distributions



galaxies, subhalos, dark matter

$$kurtosis = \frac{\langle v^4 \rangle}{\sigma^4} - 3$$

$r_{[0.2,1]}$	subhalos	galaxies	dark matter
$\sigma/v_{c,max}$	$0.665 \pm 0.007$	$0.592 \pm 0.023$	$0.5816 \pm 0.0001$
kurtosis	$-0.61 \pm 0.16$	$-0.16 \pm 0.44$	$-0.241 \pm 0.003$
$\beta$	$-0.073 \pm 0.031$	$0.17 \pm 0.11$	$0.1103 \pm 0.0005$
N	4115	339	$10.9 \times 10^6$

kurtosis  $\leq -0.2$  indicator for positive velocity bias ?

## Summary

- Selection has impact on lifetime  
subhalo sample → short lifetimes  
galaxy sample → long lifetimes  
(particles → infinite lifetimes)
- **Bias** occurs if lifetimes are different  
particles ↔ subhalos  
galaxies ↔ subhalos
- **No bias** occurs if lifetimes are similar  
particles ↔ galaxies
- Flat topped velocity profile of the subhalo sample  
is caused by tidal destruction