The cosmology dependence of the projected mass function

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The power of shear peaks

Measure the cluster abundance → cosmology constraints

Clusters detectable through:

- optical emission
- X-ray emission
- SZ effect on the CMB photons
- peaks in WL maps

Cluster observables: flux, temperature, decrement $\xrightarrow{?}$ virial mass → 3D mass function → cosmology

shear peaks → projected mass function → cosmology

easy to predict from simulations, no gas physics

Shear peaks problems

To detect WL clusters:

- knowledge of the source galaxies
- minimal shape noise
- the projection effect

WL maps are 2-dimensional, and all the structure along the line of sight contributes to the signal.

Are shear peaks sensitive to cosmology?

How do they scale with cosmology? $\longrightarrow$ Sheth-Tormen?

Structures nearby the measured cluster $\longrightarrow$ Correlated projections

Structures far away from the cluster, but on the same line of sight $\longrightarrow$ Uncorrelated or chance projections

N-body simulations

We study the lensing mass function with numerical simulations.

32 simulations of 4 cosmologies, with 8 realizations per cosmology.

GADGET, box size: 512 Mpc/h, 64M particles

fiducial cosmology: $\{\Omega_m = 0.27, \sigma_8 = 0.9\}$

variational models: $\{\Omega_m = 0.22, \sigma_8 = 0.9\}$

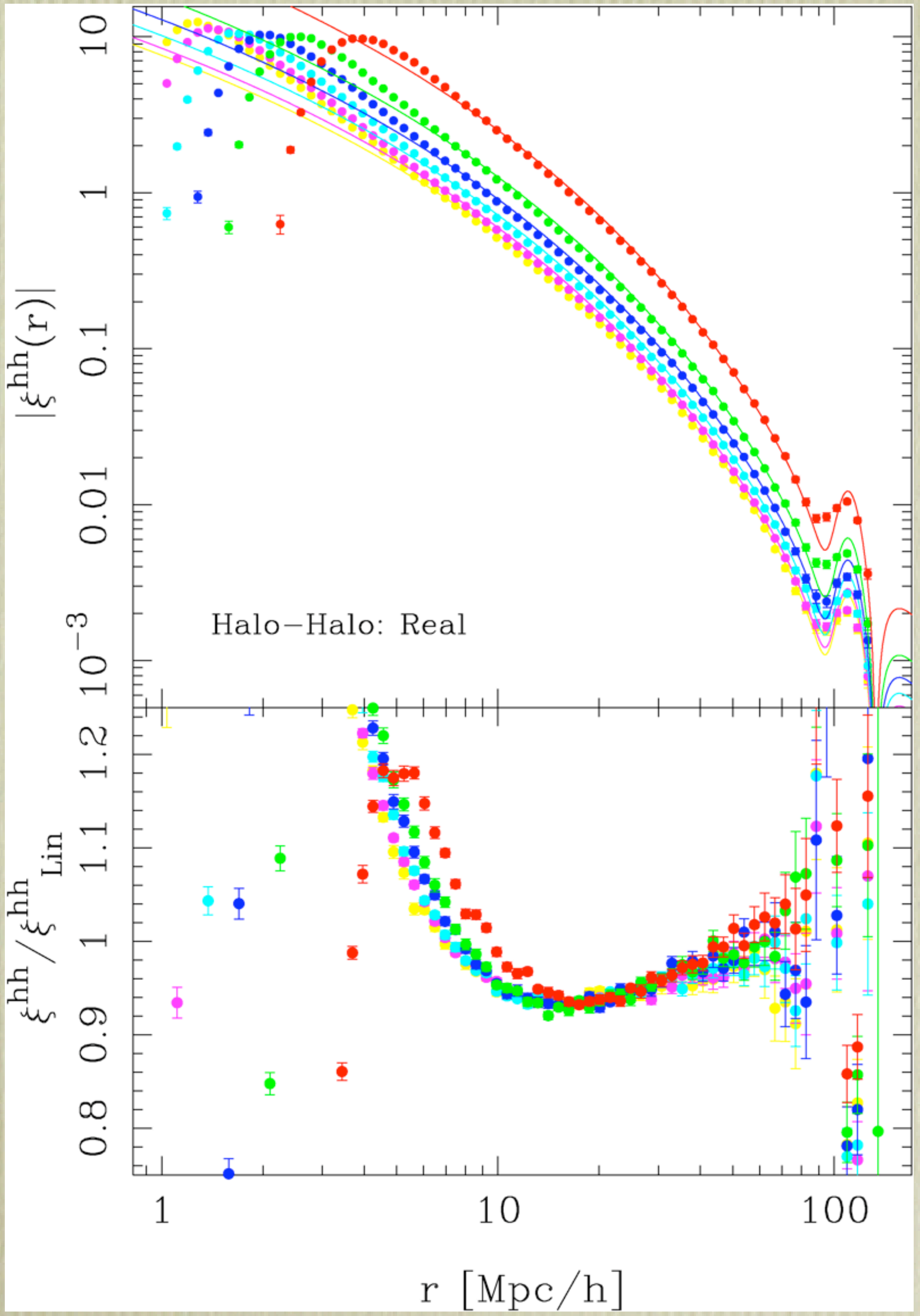
$\{\Omega_m = 0.27, \sigma_8 = 0.75\}$

$\{\Omega_m = 0.32, \sigma_8 = 0.9\}$

Our observable: the projected density field of the dark matter particles.

Divide the simulation box in slabs of different thickness and analyze the projected peak abundance in such slabs.

The cluster correlation function



study projections in slabs of 26, 51, 102, 256, 512 Mpc/h

Robert E. Smith (2009)

Halo model prediction for the correlated projections contribution to the 3D mass

$$\langle M_{ext}(M)\rangle = \langle M_{uniform}(M)\rangle + \langle M_{corr}(M)\rangle$$

$$\langle M_{uniform}(M)\rangle = \bar{\rho}\,(L - 2R_{vir}(M)) \int d^2 r_\perp \, W(\boldsymbol{r}_\perp)$$

slab thickness

filter

$$\langle M_{corr}(M)\rangle = 2b(M) \int dM_2\, M_2\, b(M_2)\, n(M_2) \int \frac{dk}{2\pi^2}\, k^2\, U(k, M_2)\, P_{lin}(k)\times$$

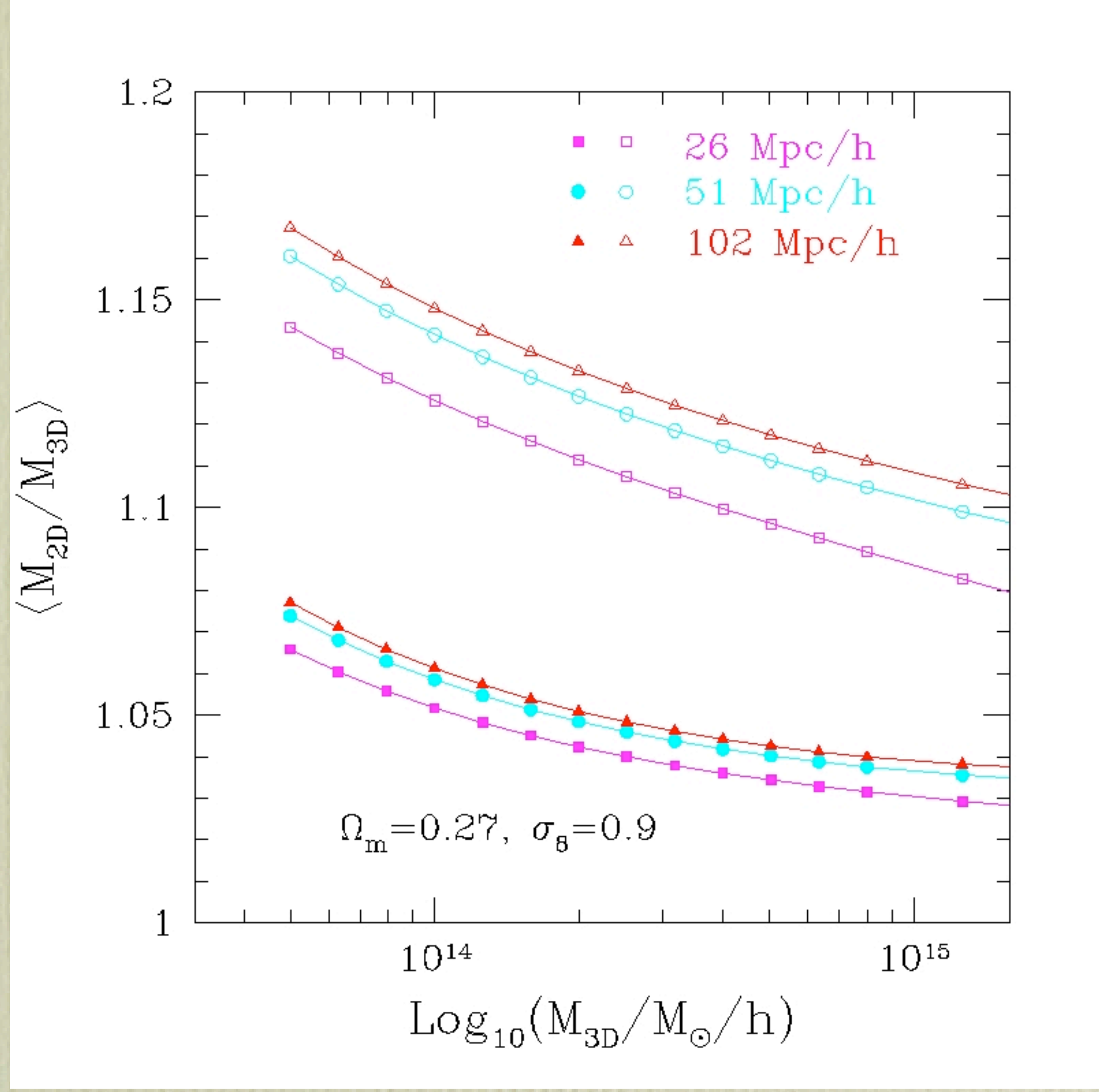
linear bias

halo profile

linear power spectrum

$$\times \int_{R_{vir}(M)}^{L/2} dz \int d^2 r_\perp j_0(k\sqrt{r_\perp^2 + z^2})\, W(\boldsymbol{r}_\perp)$$

Halo Model Prediction



top-hat filter: the change in mass is < 20%

our filter: the change in mass is < 10%

The filter

3 properties:

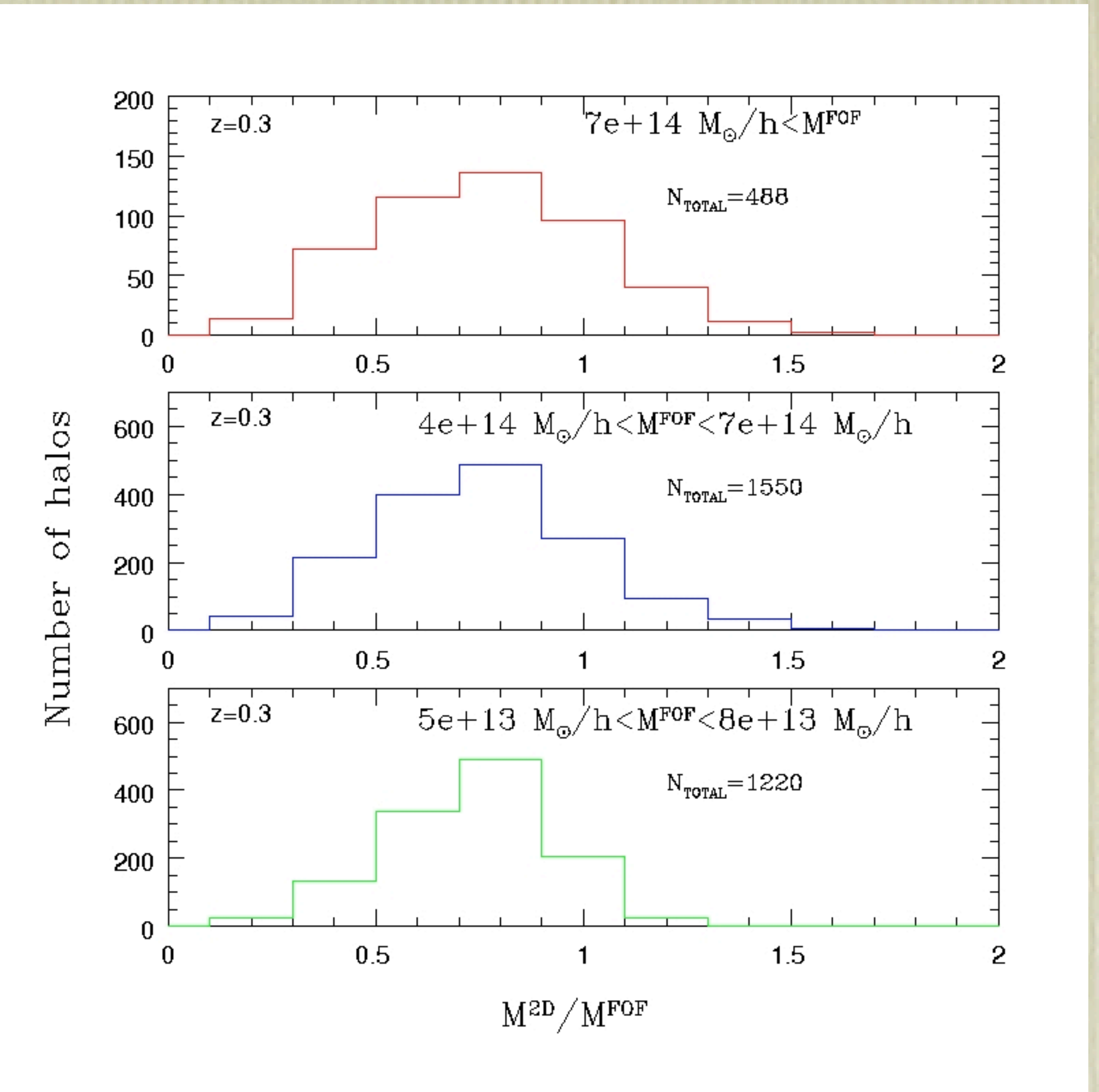
- follows the NFW density profile
- maximizes the signal-to-noise
- normalized to Sheth-Tormen masses

$$M(\boldsymbol{x_0}) = \int d^2x\, W(\boldsymbol{x_0} - \boldsymbol{x})\Sigma(\boldsymbol{x})$$

$$W(\boldsymbol{x}) = M_{ST}\, \frac{\Sigma_{ST}(\boldsymbol{x})}{\int d^2x |\Sigma_{ST}(\boldsymbol{x})|^2}$$

We filter the density field recursively, with filters of decreasing mass $\longrightarrow$ no 'halos in halos'.

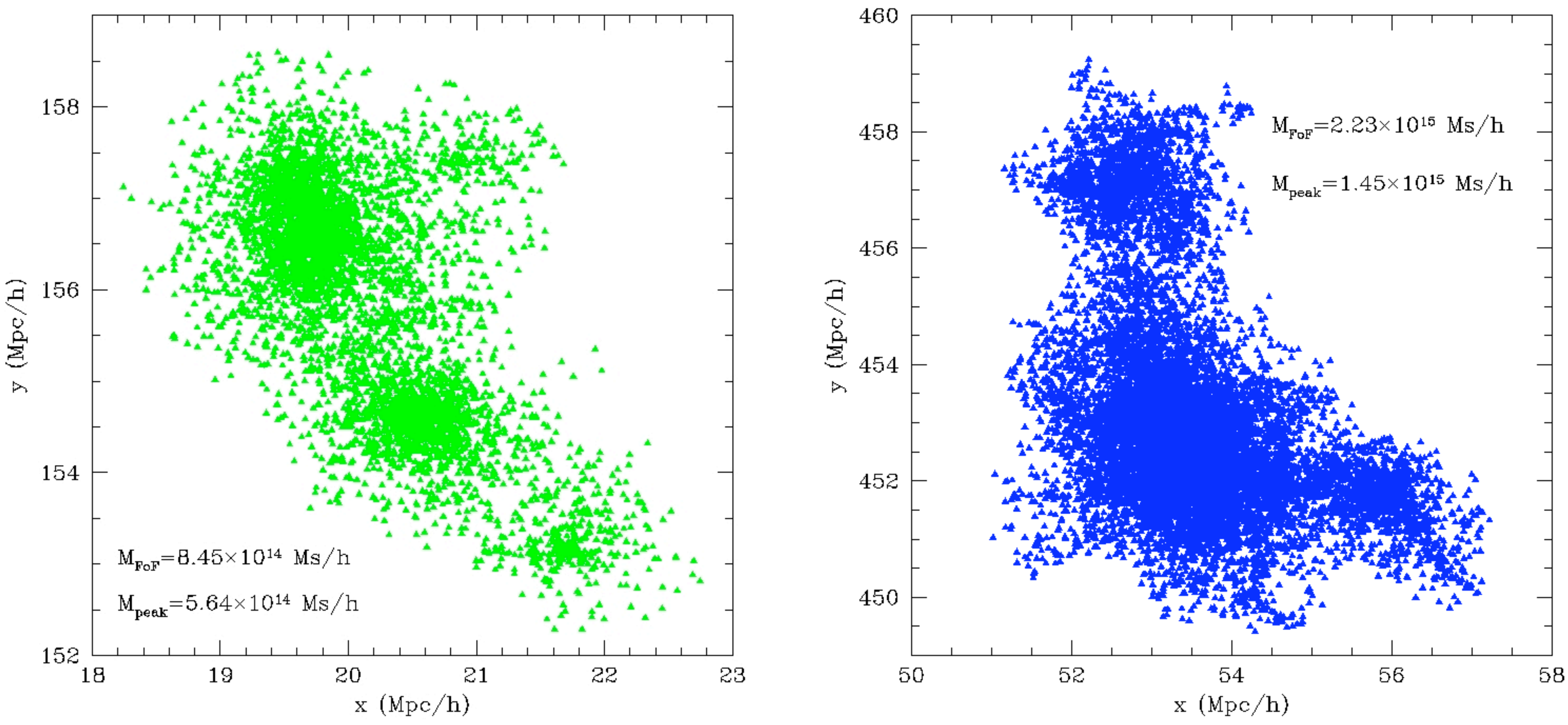
The filter response



Apply the filter to individual FoF halos

halo triaxiality → The filter shifts the FoF masses to lower masses

Examples of misbehaved halos:

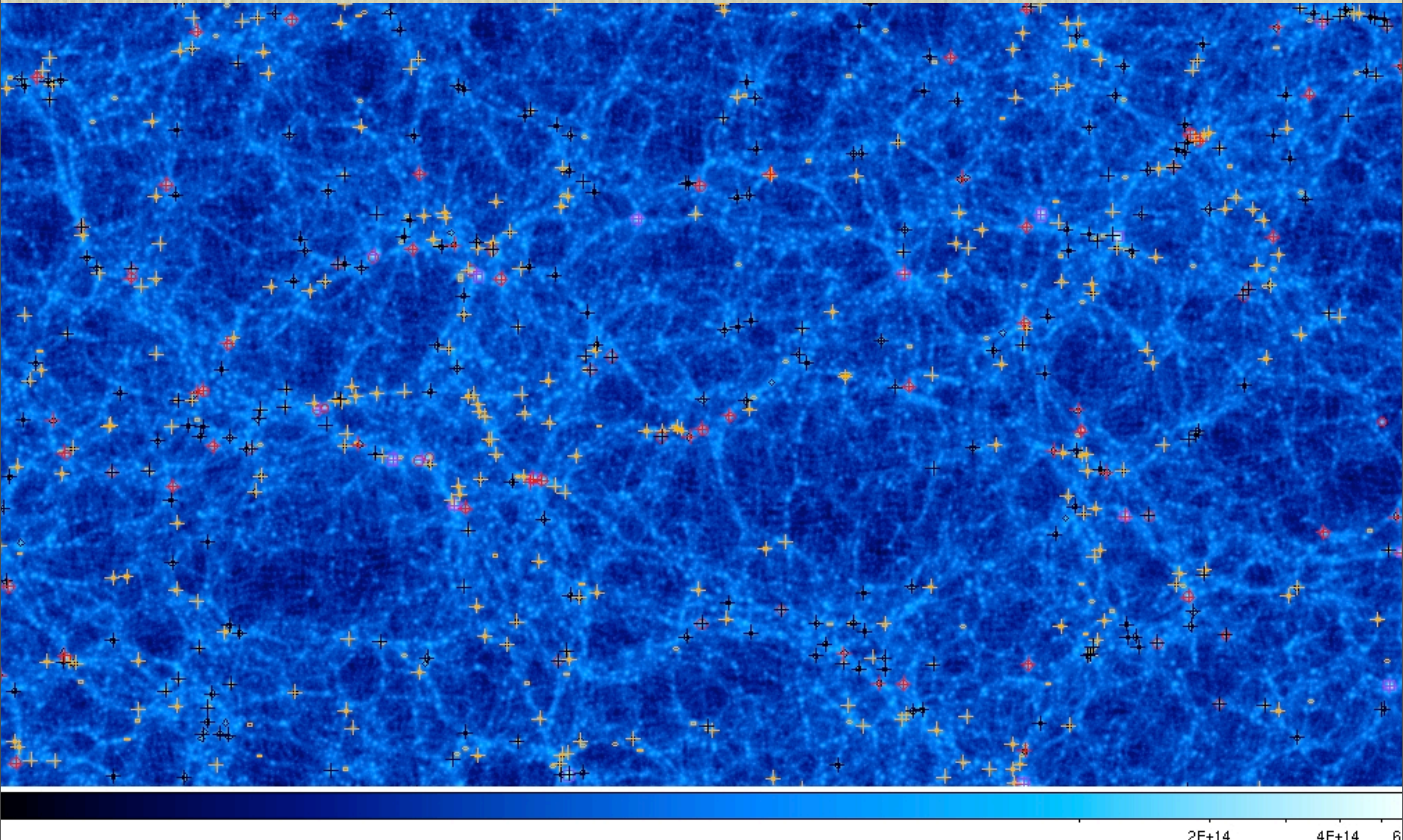


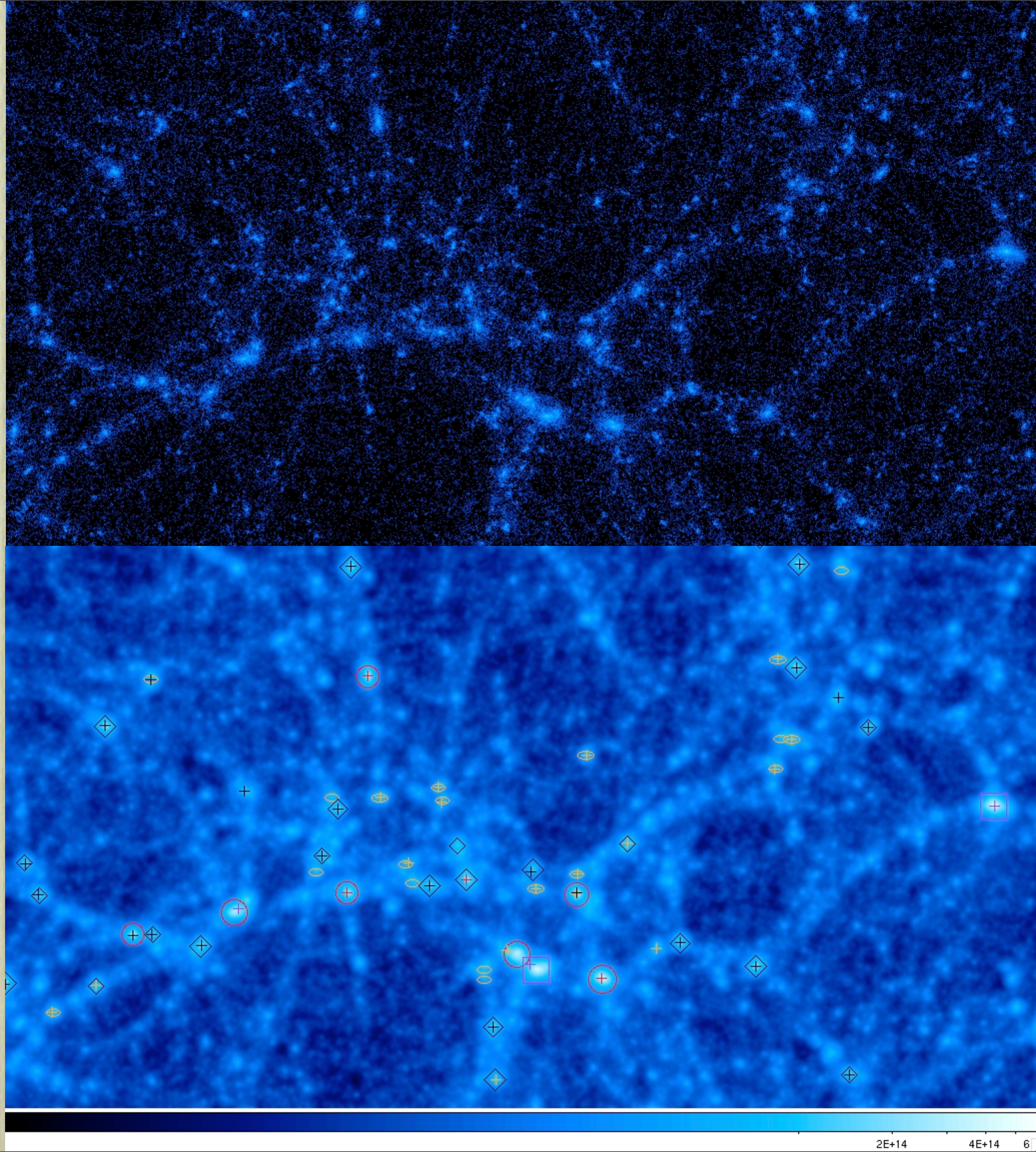
67 %

65 %

Filtered maps

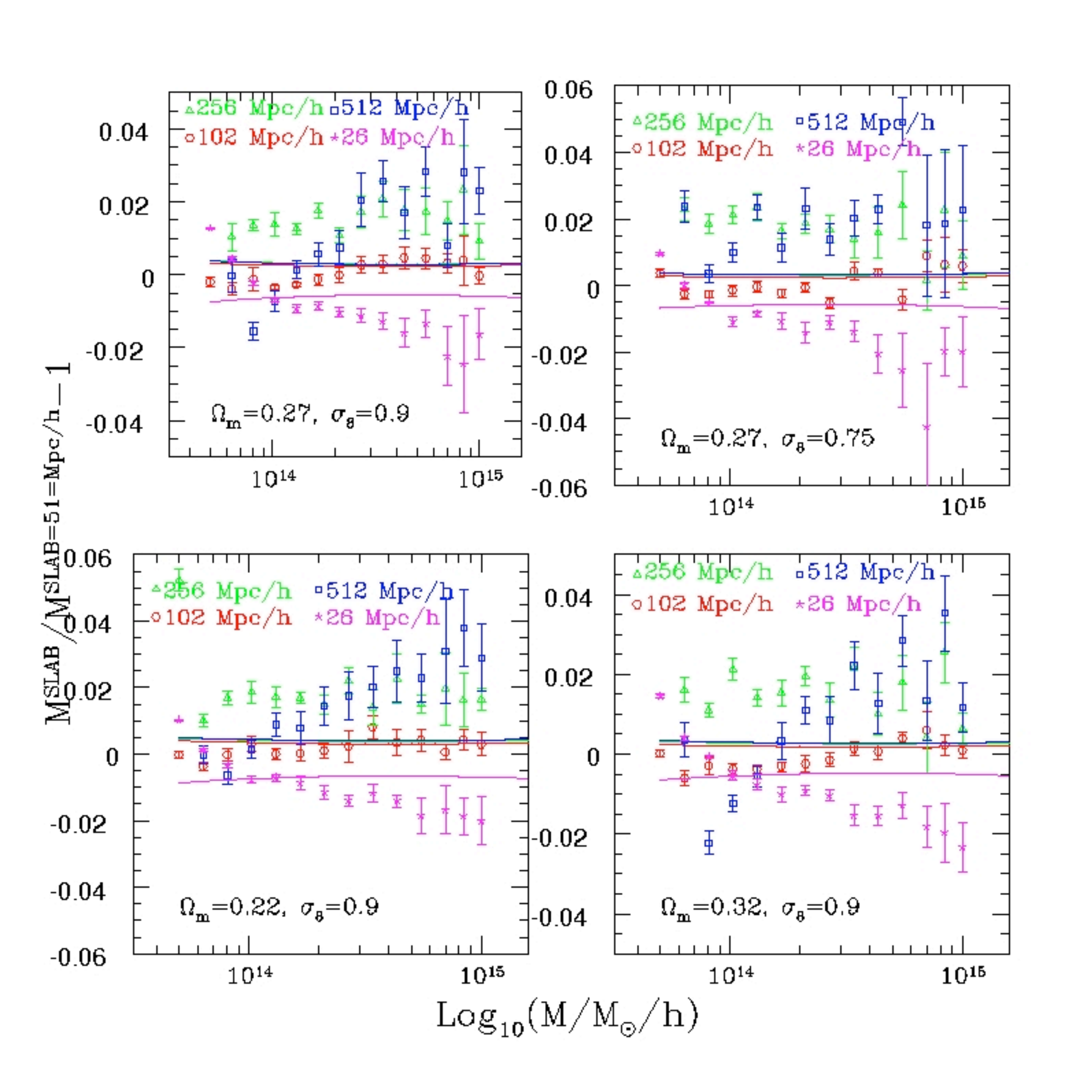
512 x 280 Mpc/h





130 x 70
Mpc/h

The mass change induced by correlated projections

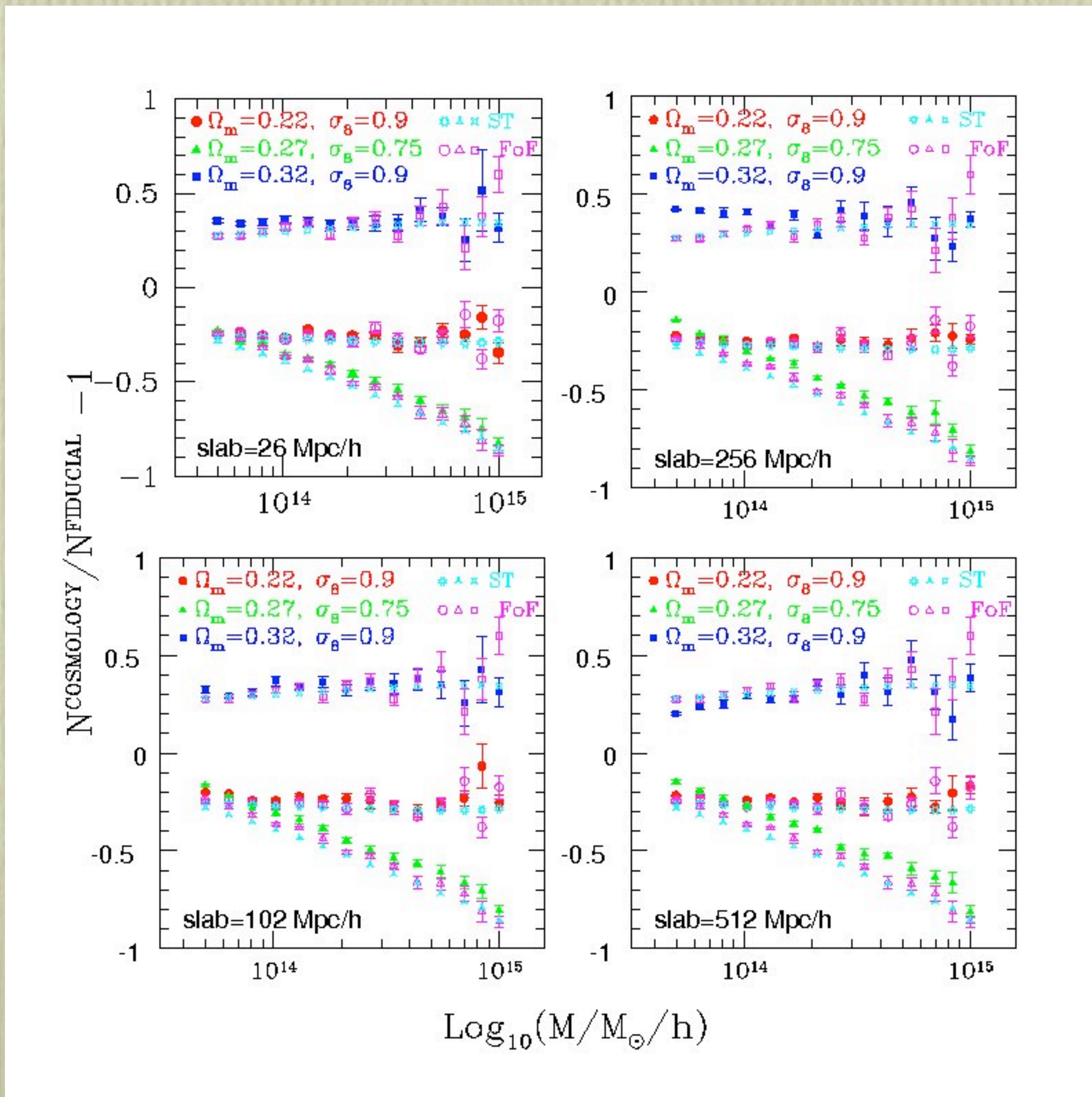


We trace every peak in the fiducial slab among the peaks corresponding to the other slabs

Halo model prediction agrees with the measurements

Theory & Data → change in mass < 3%

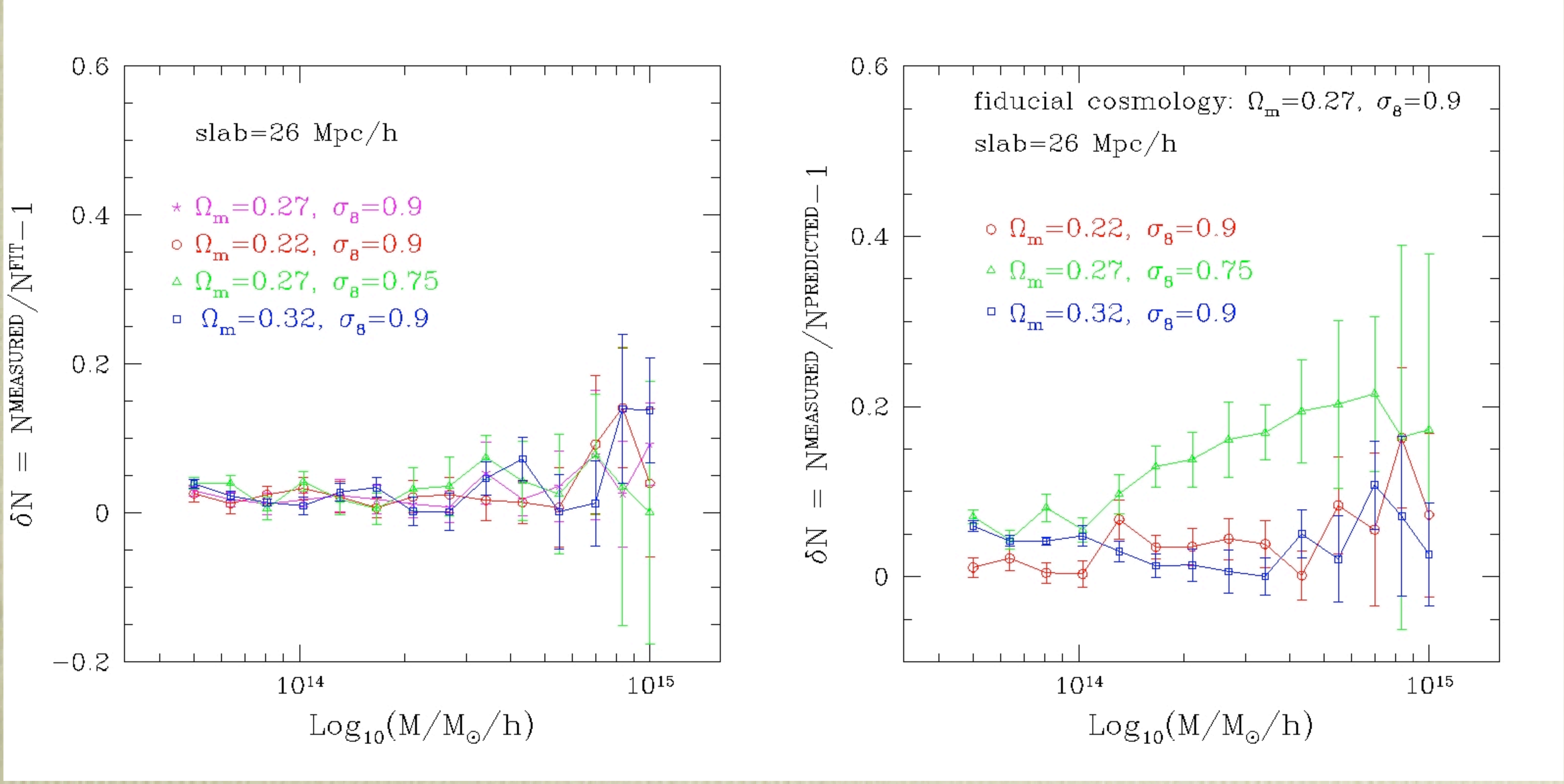
The scaling with cosmology of the projected mass function



Ratio of the mass functions for cosmology X and for the fiducial cosmology

Peaks, FoF, and Sheth-Tormen

Modelling the projected mass function



Sheth-Tormen form

Predictions from the fiducial model

Conclusions

N-body and analytical study of correlated projections on the 2D mass function.

Correlated projections induce a shift in 3D masses of <10%. This shift depends on the choice of filter.

The most important result: the projection mass function varies with cosmology in the same way as the 3D and ST mass functions.

It is possible to model the projected mass function using the functional form of the Sheth-Tormen mass function.

Further work is needed to see if this is also true for actual lensing observables, i.e. shear or convergence.