Towards a Universal Halo Mass Function for f_{NL} Cosmologies

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In preparation

Halo mass function

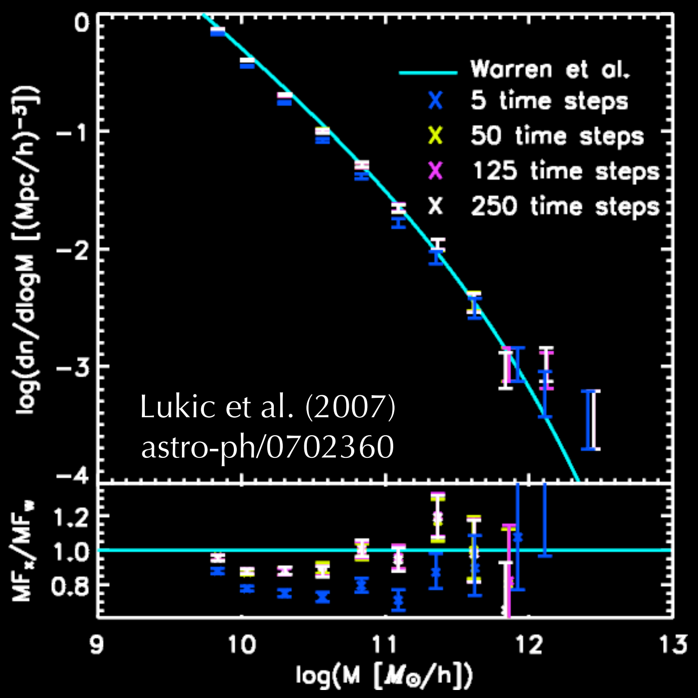
Lots of interest in using halo counts as a cosmological probe (SZ, optical,...).

- Mass function can be computed precisely (~5%) and robustly for standard cosmology (Jenkins et al. 01, Warren et al. 03)

- dN/dM appears universal — i.e. f(σ) — for standard cosmologies

$$\sigma^2(M,z) = \frac{1}{2\pi^2}\int_0^\infty k^2 P(k) W^2(k,M)\,dk$$

- Abundance of rare objects is exponentially sensitive to cosmological parameters, power spectra (Holder & Haiman 01) and we could hope for 5% on σ_8 and Ω_m (probably optimistic)



Non-gaussianity and growth of structure

- Simplest inflationary models predict small but nonzero non-gaussianity. for $\Phi \rightarrow \Phi + f_{NL} (\Phi^2 - \langle\Phi\rangle^2)$, expect $f_{NL} \sim O(1)$ (e.g. Maldacena 2003)

- Current WMAP constraints: $f_{NL} \lesssim O(100)$

- The abundance of rare peaks can be strongly affected by this sort of skewness $\Rightarrow$ Can we constrain f_{NL} with dN/dM?

- So far, qualitative estimates have been made using (extended) Press-Schechter, but PS mass function is off by an order of magnitude for cluster-sized halos (Verde et al. 01, Scoccimarro 04, Sefusatti et al. 06)

- Simulations are required to properly address the effect of f_{NL} on dN/dM

Generating ICs for N-body simulations with $f_{NL} \neq 0$

(1) Generate a realization of Φ as Gaussian field with a (nearly) scale invariant power spectra

(2) Add the quadratic term in real space

(3) Apply transfer function in Fourier space

(4) Use Zeldovich approximation to generate the particle data

Caveat: finite volume effect could be tricky due to mode-coupling but it seems to be unimportant

Large scale structures depend on f_{NL}

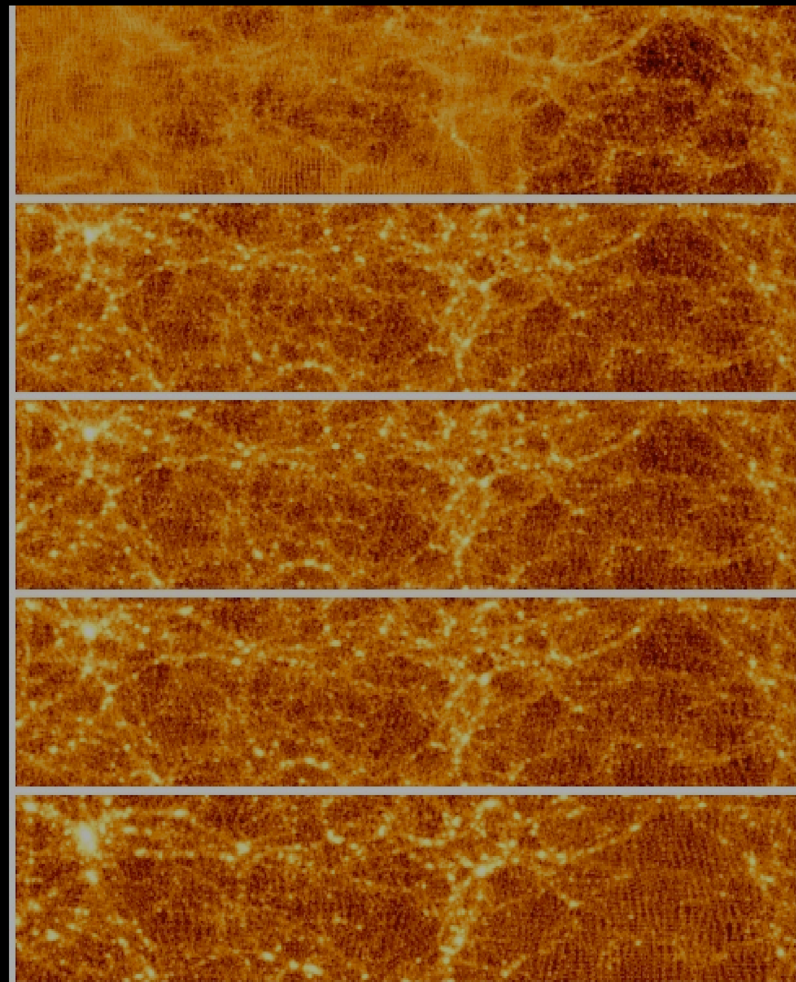
f_{NL}=-3000

f_{NL}=-300

f_{NL}=0

f_{NL}=+300

f_{NL}=+3000



80 Mpc/h

375 Mpc/h

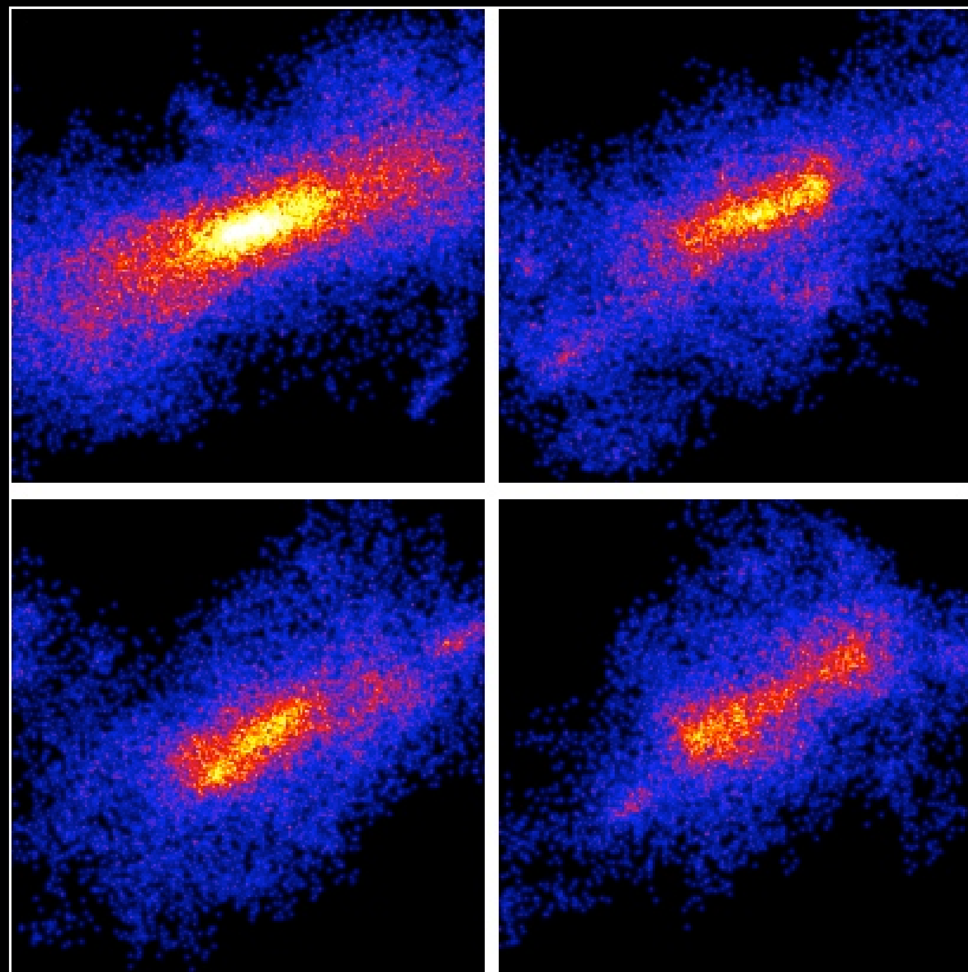
- Under-dense region evolution decrease with f_{NL}
- Over-dense region evolution increase with f_{NL}

- Same initial conditions, different f_{NL}
- Slice through a box in a simulation $N_{part}=512^3$, L=800 Mpc/h

Looking at individual clusters

f_{NL}=+3000
M=1.2 10^{16} $M_\odot$

f_{NL}=+3000
M=5.9 10^{15} $M_\odot$

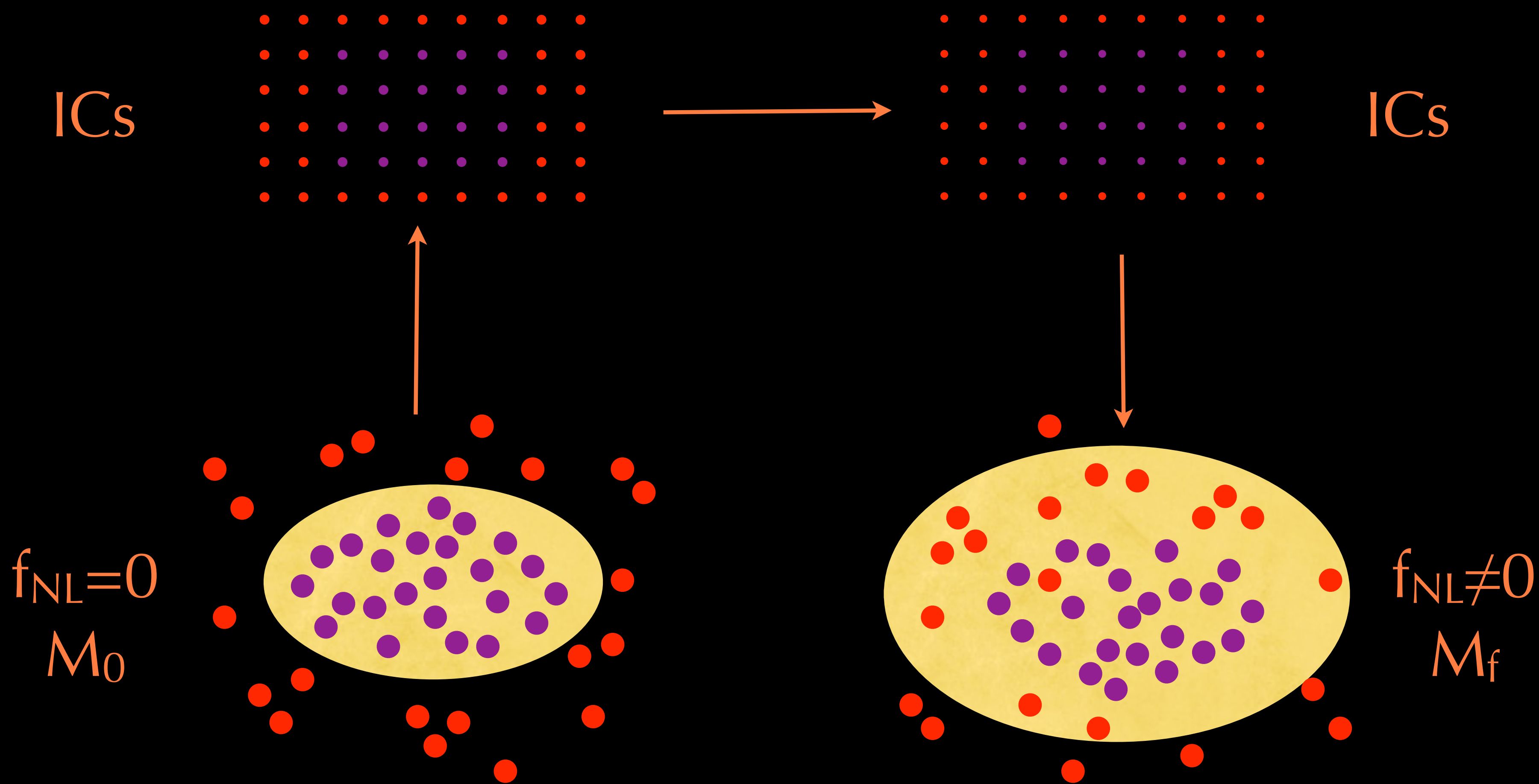


f_{NL}=0
M=5.1 10^{15} $M_\odot$

f_{NL}=-300
M=4.3 10^{15} $M_\odot$

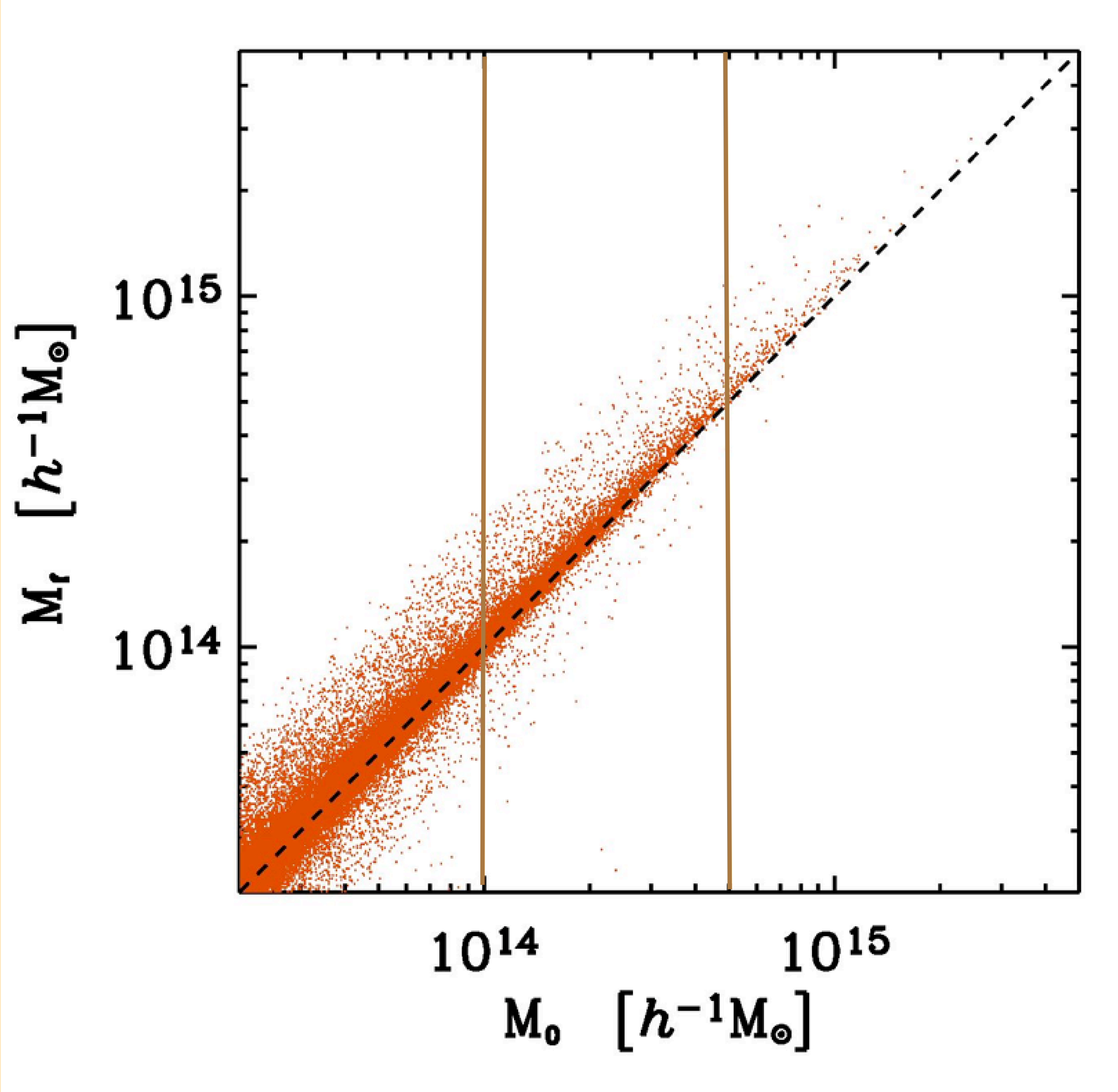
- Most massive cluster in our simulation
- For small enough f_{NL}, same peaks arise, with different heights (implying different masses)
- Can we extend to any cluster?

Halo matching procedure



- Starting from a cluster catalog
- For all the particles in a given halo of mass M_0 in a $f_{NL}=0$ we can determine which group they end up in for $f_{NL}\neq 0$ and look at the mass distribution of those groups
- We define, M_f, the matching mass to M_0 as the mode of this distribution
- There is noise in this mapping because the cluster catalog itself is noisy

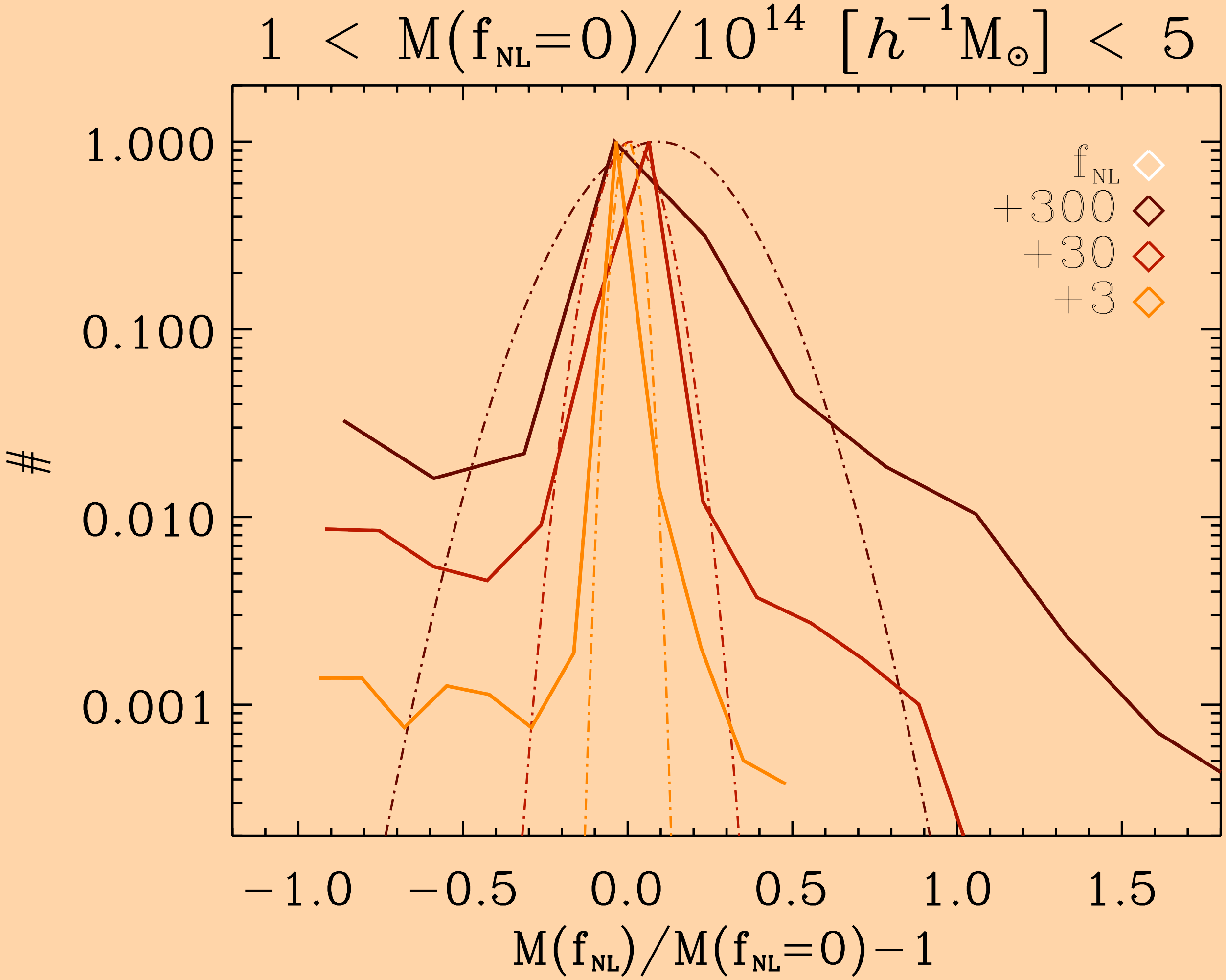
Building the $P(M_f|M_0)$ distribution



$f_{NL} = 300$

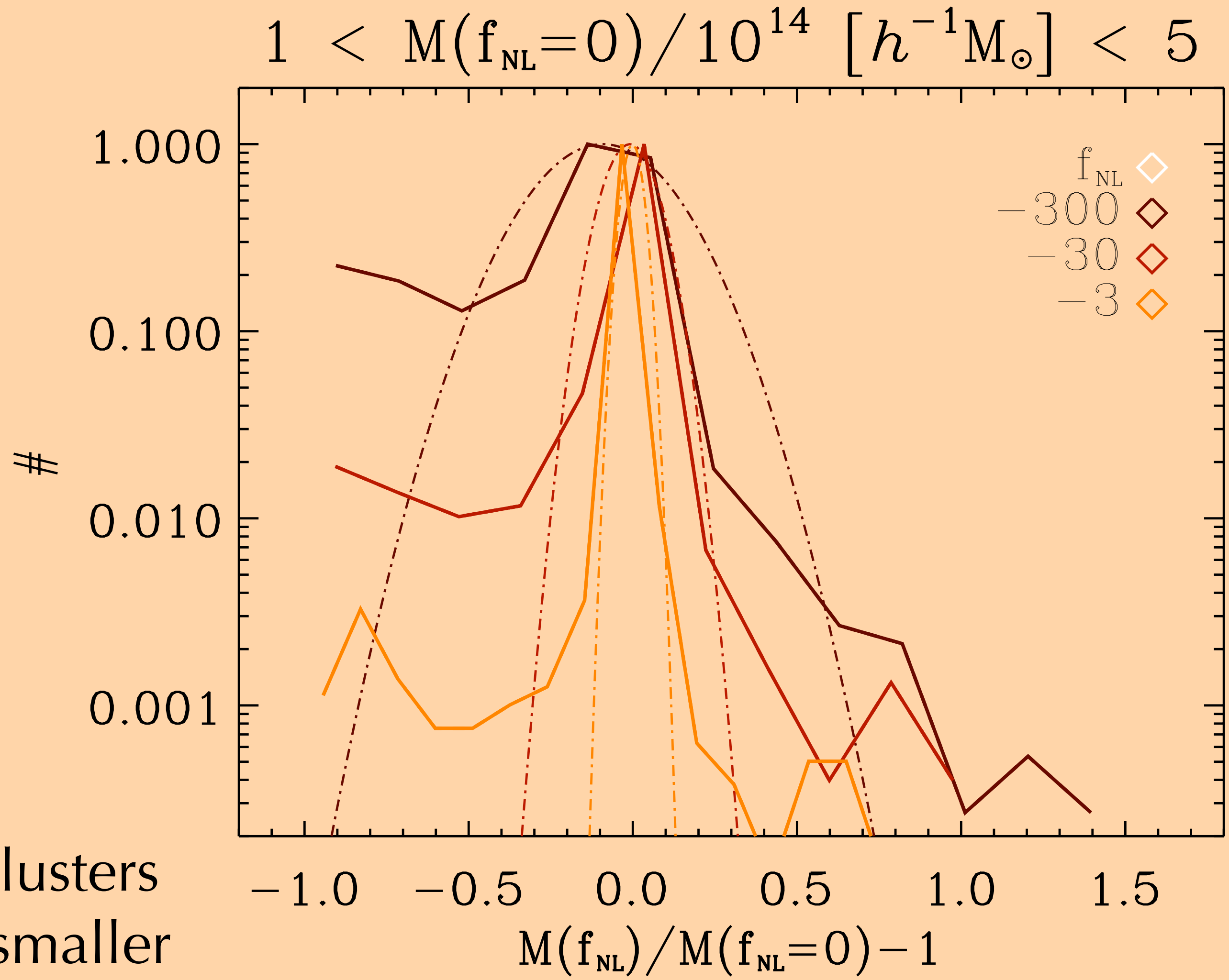
Statistical approach to this mapping for $f_{NL}>0$

$P(M_f \mid M_0)$ binned in M_0



Statistical approach to this mapping for $f_{NL}<0$

$P(M_f \mid M_0)$ binned in M_0



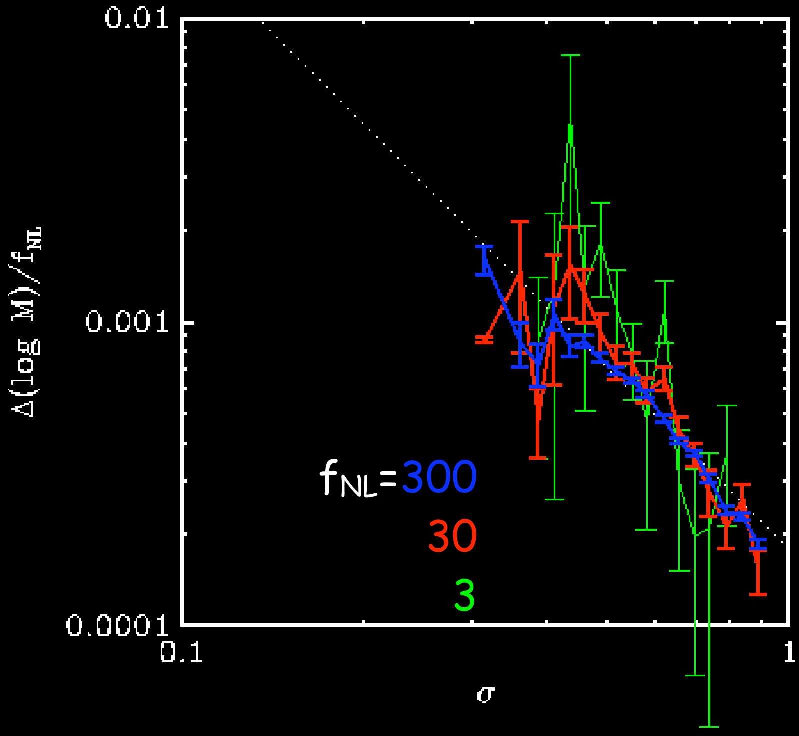
Massive clusters split into smaller clusters

Towards a fitting function

- If the mapping $M_0 \rightarrow M_f$ is described by a PDF $dP/dM_f(M_0)$, then the non-gaussian mass function is a convolution over the (known) gaussian mass function

$$\frac{dN}{dM} = \int \frac{dP(M_f|M_0)}{dM_f} \frac{dN}{dM_0} dM_0$$

(e.g. Jenkins)

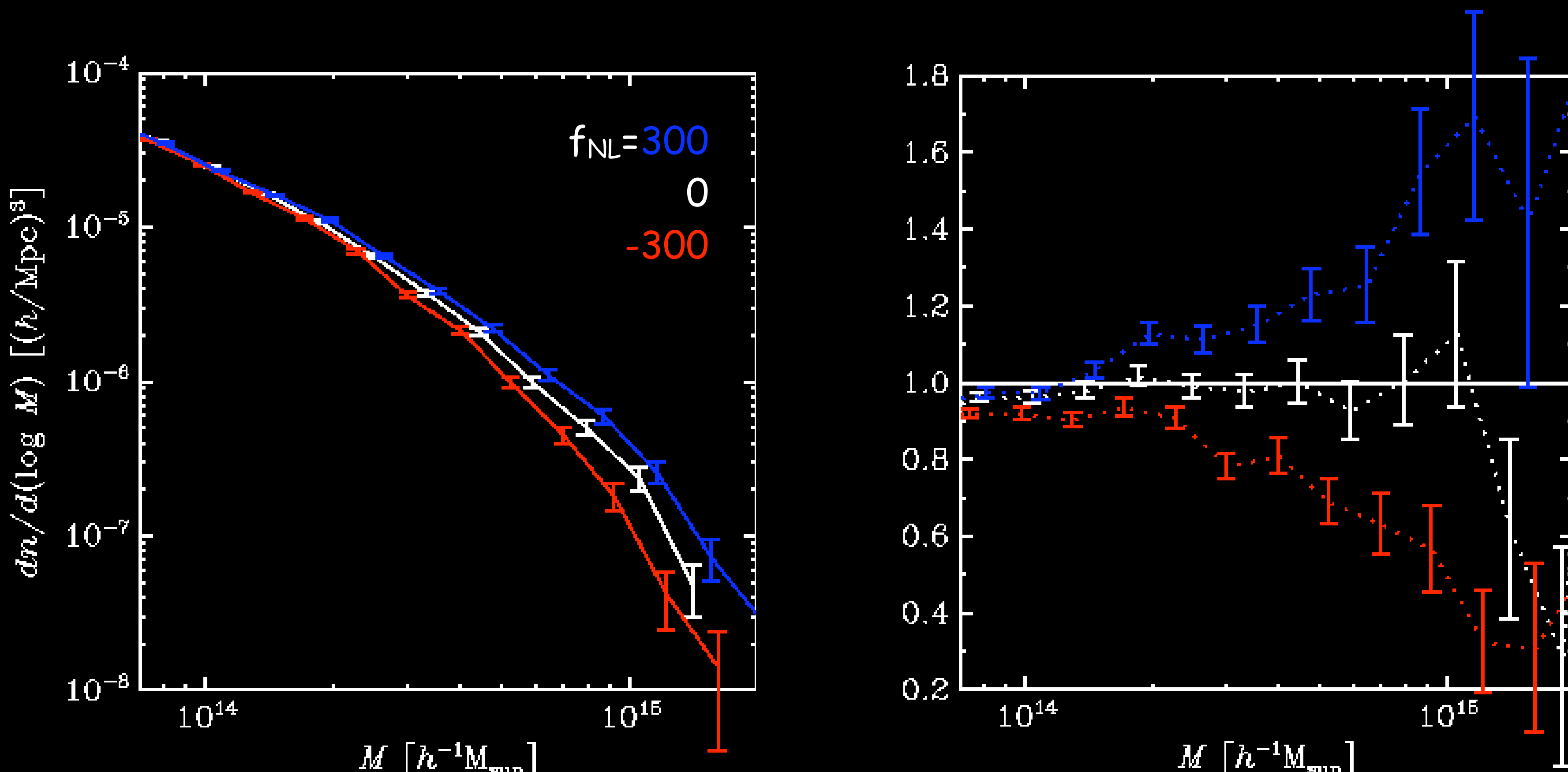


- We thus aim at fitting the mean and rms of $\Delta(\log M)(z)$
- The simplest thing to do is to consider a… Gaussian…
- We'd expect the mean of the PDF to be shifted by $\Delta(\log M) \propto f_{NL}$
- We find that a good fit is given by

$$\left[\frac{\bar{M}_f}{M_0}\right] - 1 = 6.\ 10^{-5} f_{NL} \sigma_8\ \sigma(M_0, z)^{-2}$$

$$\sigma\left(\left[\frac{\bar{M}_f}{M_0}\right] - 1\right) = 0.012\ (f_{NL}\sigma_8)^{0.4}\ \sigma(M_0, z)^{-0.5}$$

Mass function from N-body simulation...

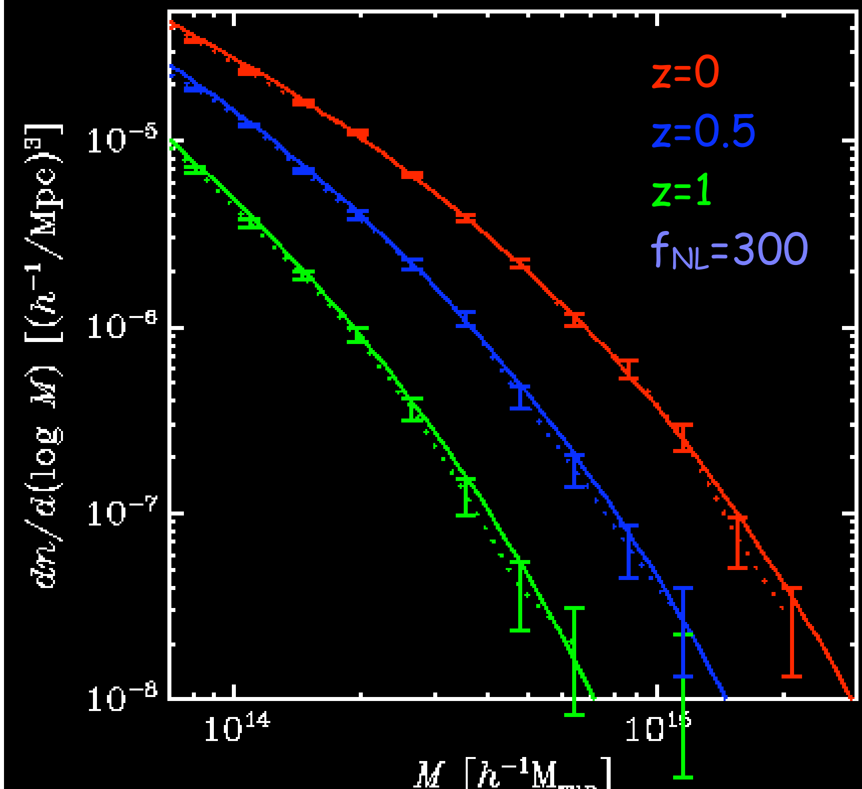


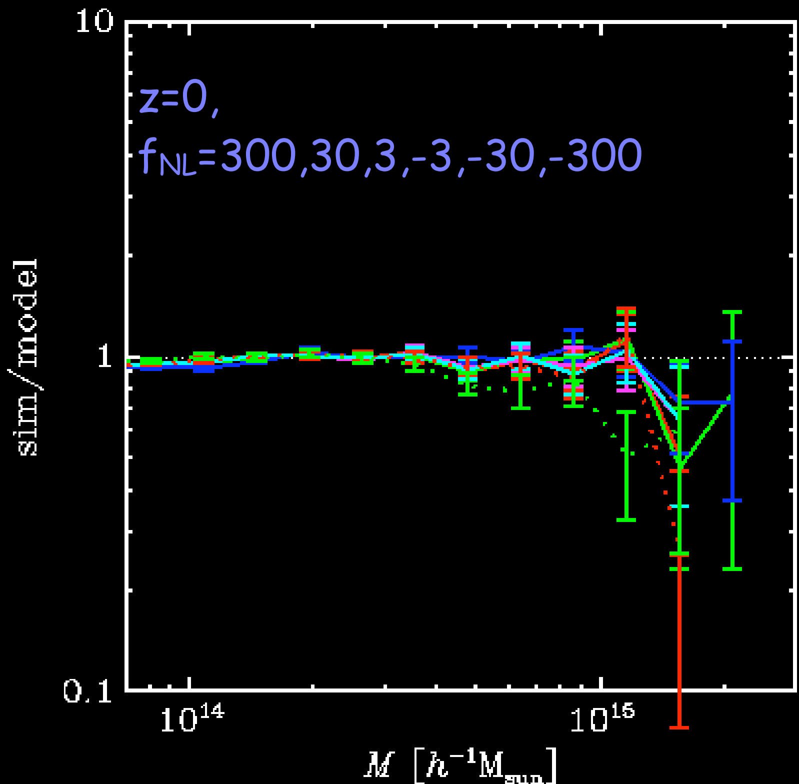
$N_{part}=512^3$, L=800 Mpc/h, z=0

Comparison to the fitting formula

The PDF appears non-Gaussian, but if we approximate it as a Gaussian with mean and variance given earlier, then we find :

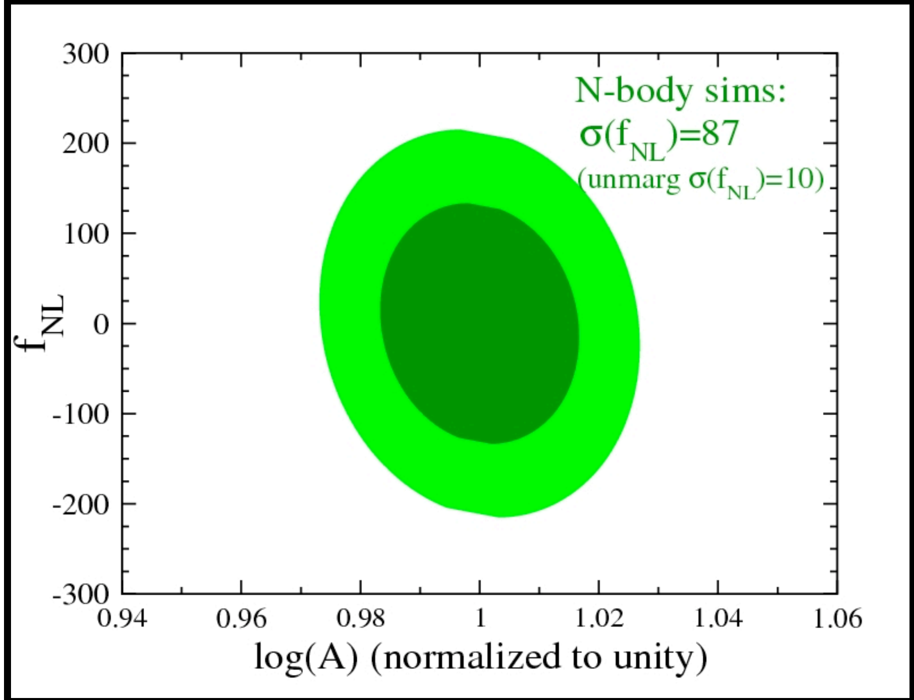
$$\frac{dN}{dM_f} = \int \frac{dP(M_f|M_0)}{dM_f} \frac{dN}{dM_0} dM_0$$

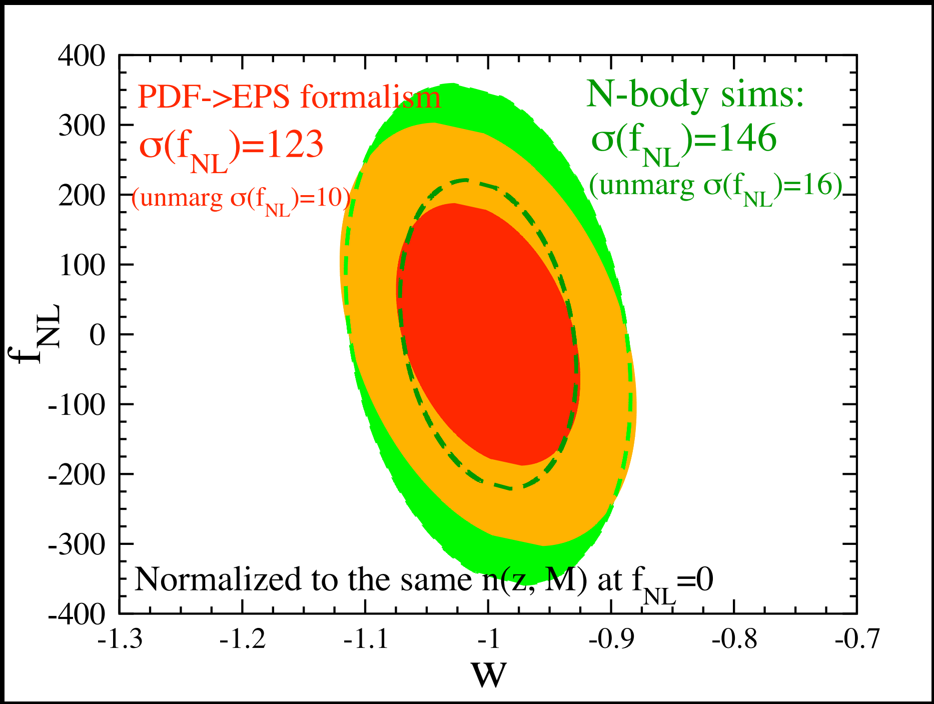




Shall we worry about such discrepancies?

SPT (dN/dM) simulations with Planck prior





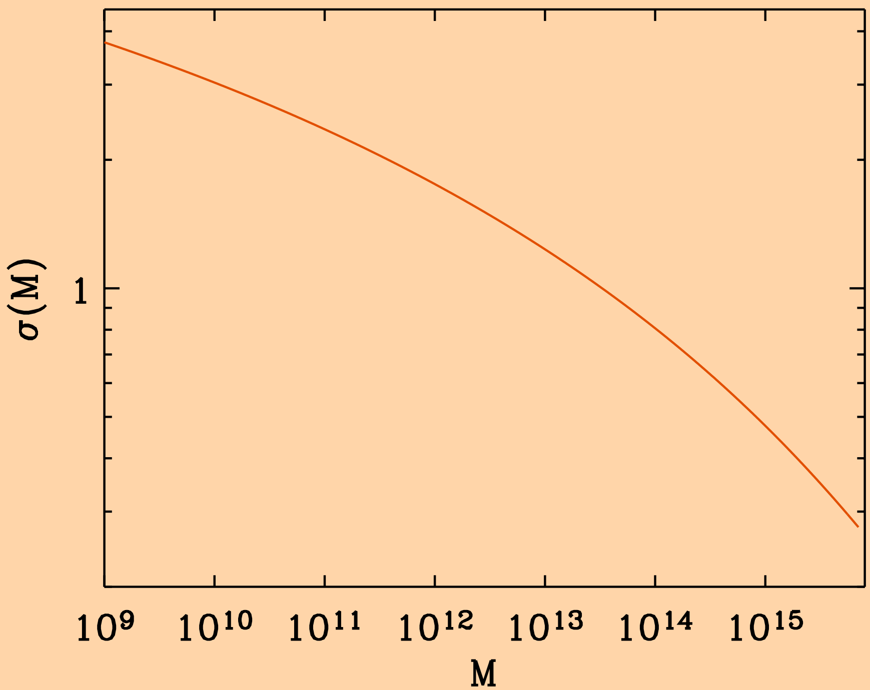
Preliminary

Can we hope to measure f_{NL} with high-z halo counts?

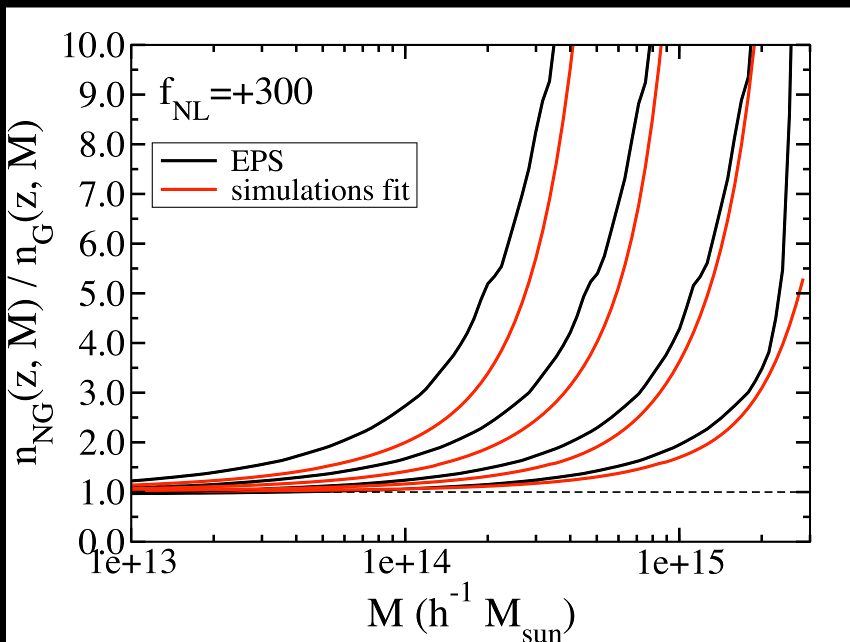
- If our ansatz for the mapping relation is correct then it suggests that what matters is $\sigma(M,z)$ and not $M/M_*(z)$

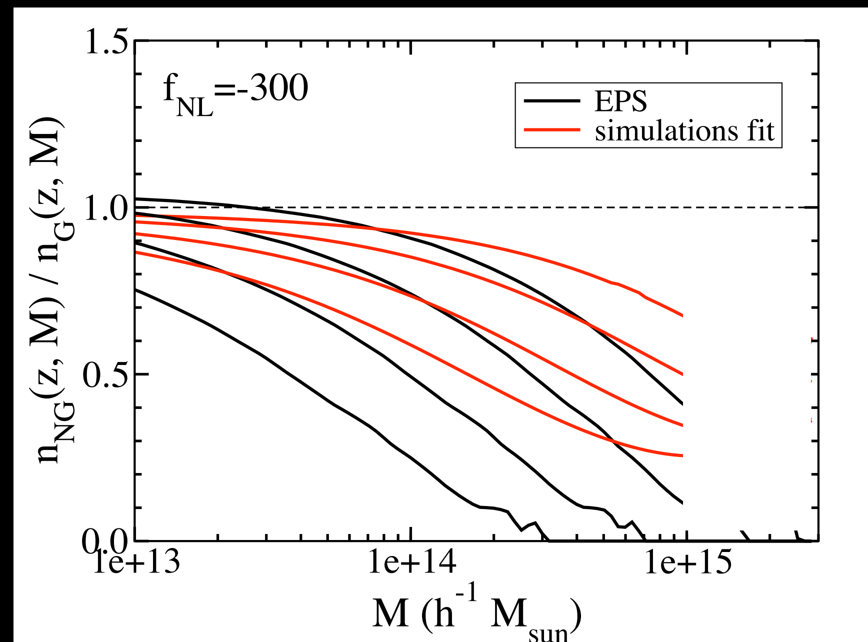
- For example, high-z QSOs or galaxies, even though they have M/M_* greater than 200 or so belong to 10^{12} halos and thus lead to a 2% effect for fnl~300 at z=6

- This is to be compared to a 25% effect at z=1 for a 10^{15} object



Comparison with previous prescriptions





Conclusions

- We propose a simple but accurate fitting formula for a generalized non-Gaussian mass function
- The accuracy of this prescription is of order the uncertainties in the usual ΛCDM mass function, i.e. ~5%
- Should be of direct relevance for future or current cluster count surveys like SZA, SPT, ACT, Planck
- But still a small effect and limited by the accuracy in the mass measurement

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