Halo mass function with f_{NL}, g_{NL} and τ_{NL}

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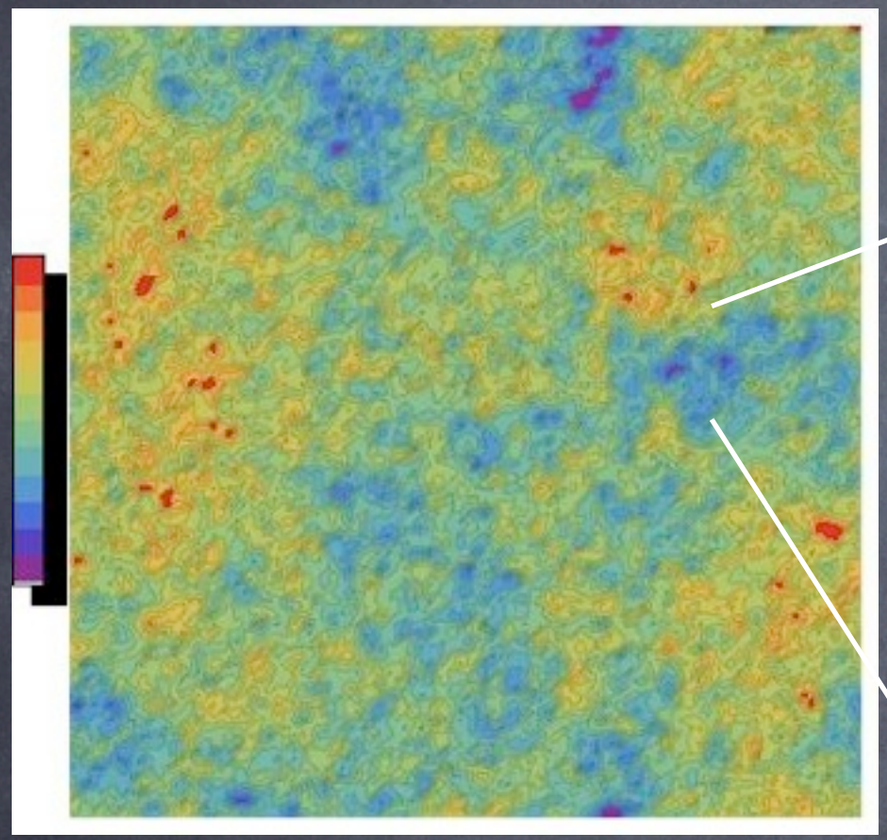
ML is grateful for support from the Friends of the Institute for Advanced Study

Outline

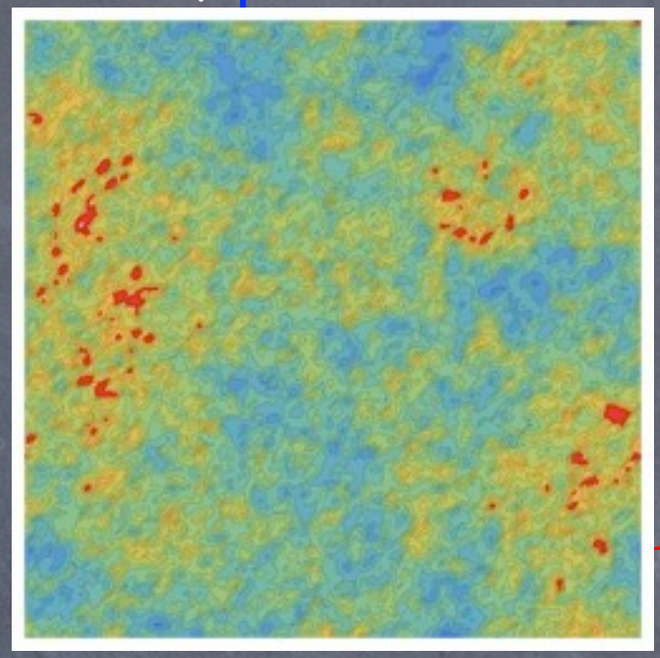
- Three simple local models: f_{NL}, g_{NL}, τ_{NL}
- Primordial non-Gaussianity in the halo mass function
- Analytic estimates & N-body results
- Conclusions

$$\Phi(x)=\Phi_G(x)+f_{NL}(\Phi^2(x)-\langle\Phi^2\rangle)$$

a Gaussian random field, Φ



same variance, positive skewness



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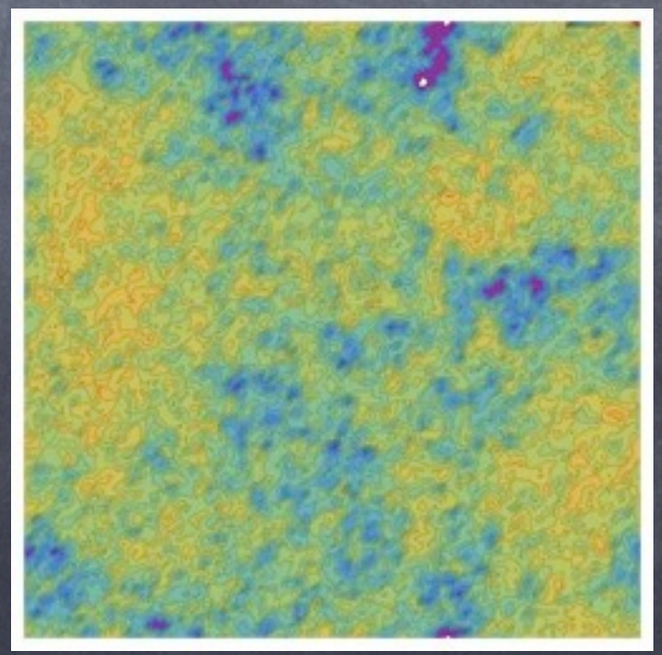
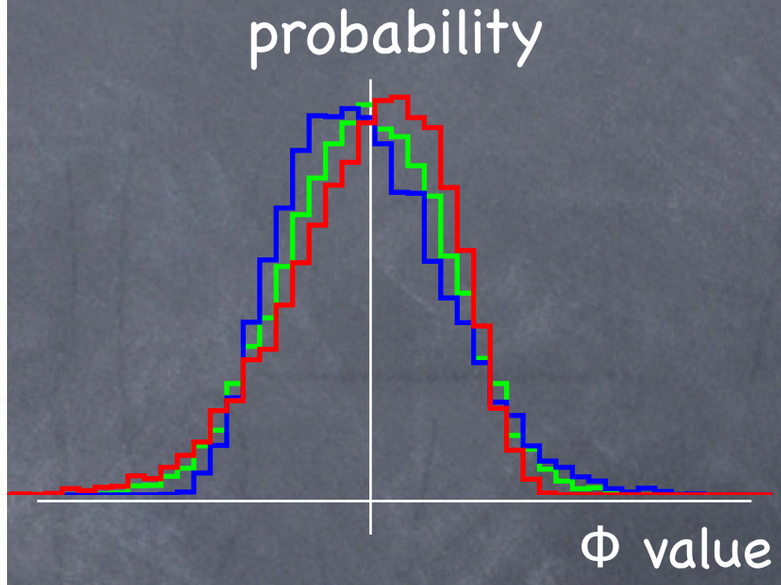




(Φ=primordial gravitational potential)

skewness $\langle\Phi^3\rangle \sim f_{NL}\langle\Phi_G^2\rangle^2$

kurtosis $\langle\Phi^4\rangle_c \sim f_{NL}^2\langle\Phi_G^2\rangle^3$

$-10 < f_{NL} < 74$

WMAP, Komatsu et al 2010

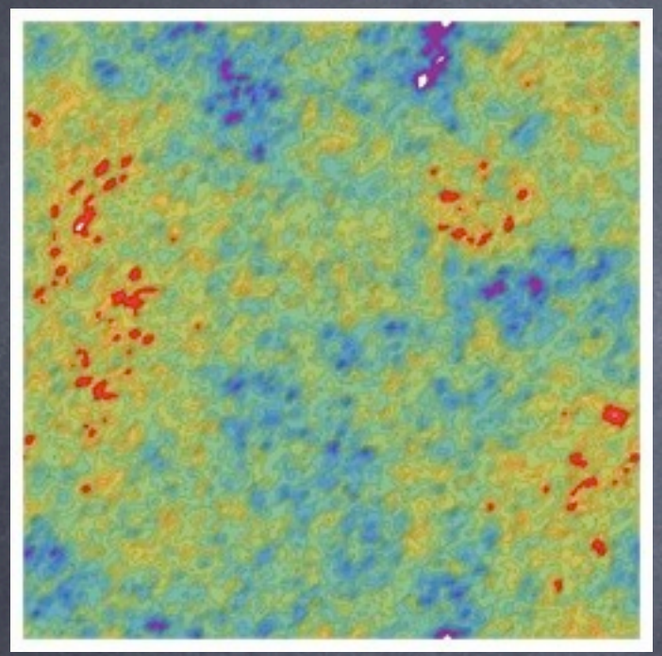
Salopek and Bond 1990; Gangui, Lucchin, Matarrese, Mollerach 1994; Komatsu and Spergel 2001

What about

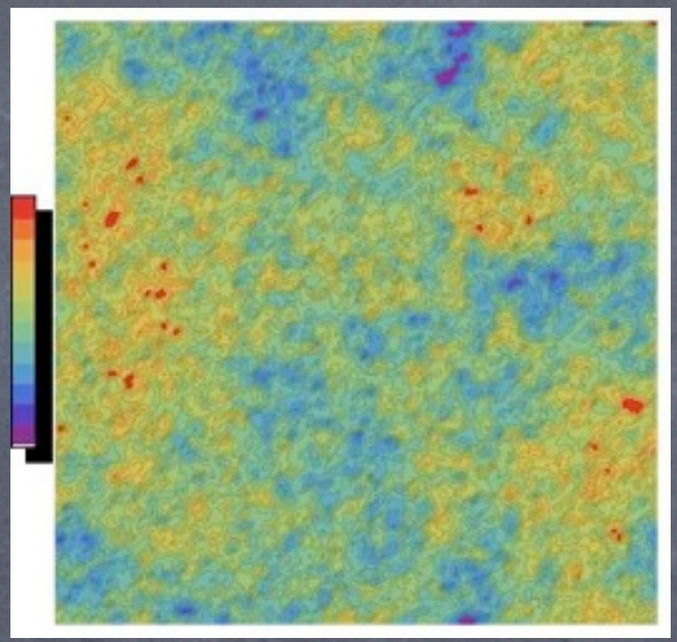
$$\Phi(x) = \Phi_G(x) + g_{NL}\,(\Phi_G(x)^3 - 3\Phi_G(x)\langle\Phi_G^2\rangle)?$$

"g_{NL}"

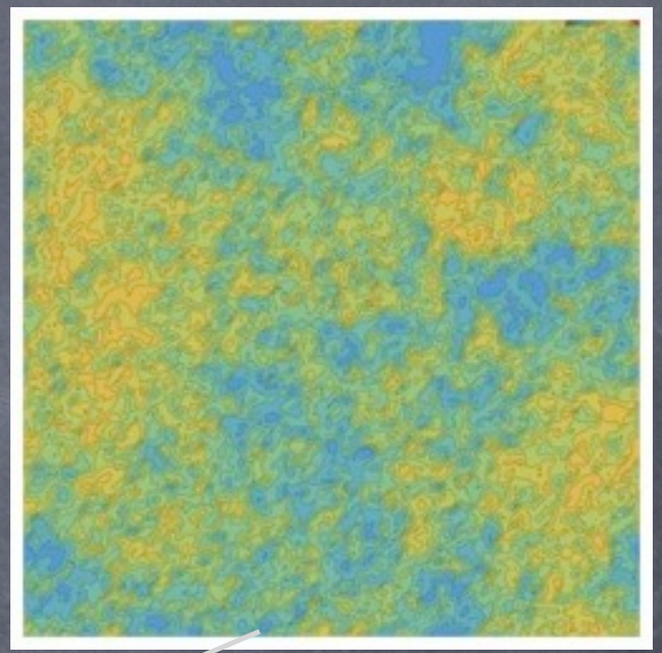
$g_{NL} > 0$: positive kurtosis

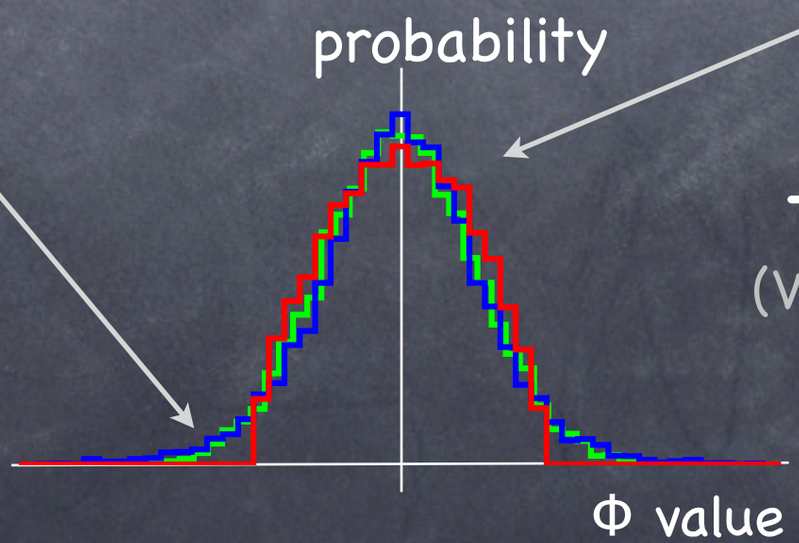


Gaussian



$g_{NL} < 0$: negative kurtosis





current constraints:

$-12 < g_{NL}/10^5 < 16$

(WMAP, Fergusson et al 2010)

NO skewness:

kurtosis:

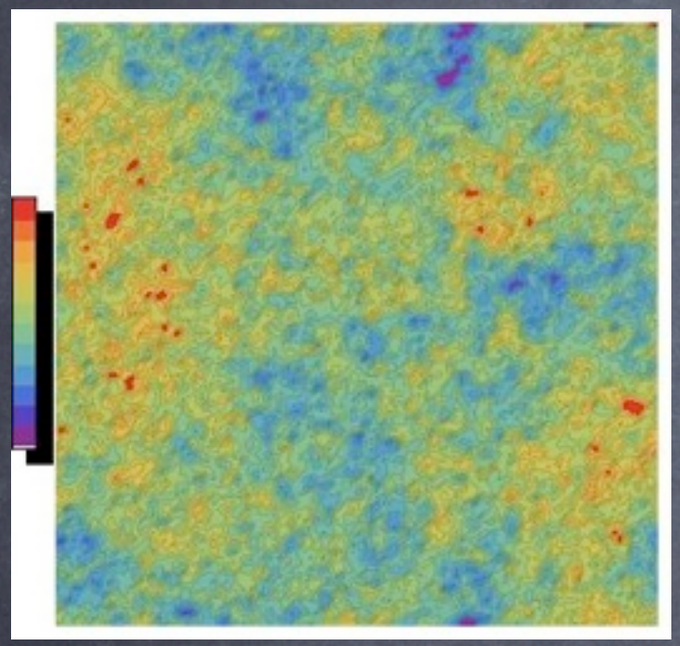
$$\langle\Phi^4\rangle_c \sim g_{NL}\langle\Phi_G^2\rangle^3$$

(Okamoto and Hu 2002; Enqvist and Nurmi 2005)

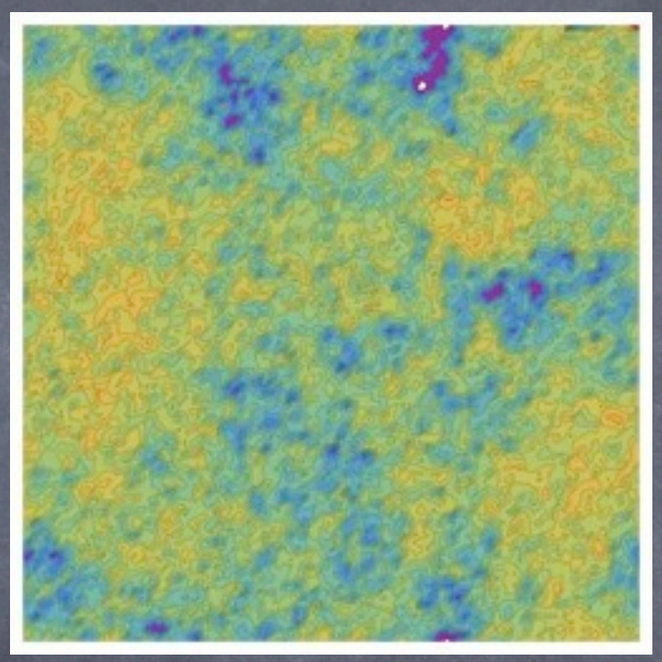
"τ_{NL}"

$$\Phi(\mathbf{x}) = \varphi_{G,i}(\mathbf{x}) + \varphi_{G,c}(\mathbf{x}) + \tilde{f}_{NL}\left(\varphi_{G,c}^2(\mathbf{x}) - \langle\varphi_{G,c}^2\rangle\right)$$

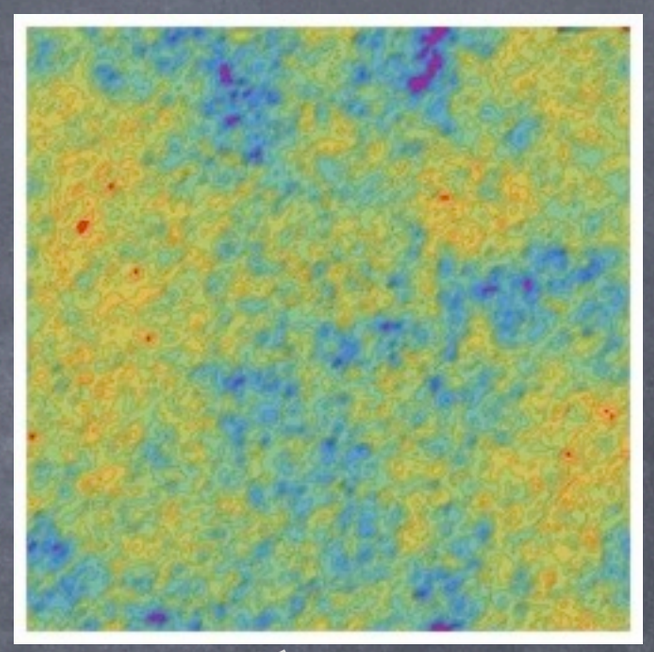
Gaussian



negative skewness and usual kurtosis: $\tau_{NL} = (6/5 f_{NL})^2$



positive skewness and larger kurtosis: $\tau_{NL} > (6/5 f_{NL})^2$



skewness $\langle\Phi^3\rangle \sim f_{NL}\langle\Phi_G^2\rangle^2$

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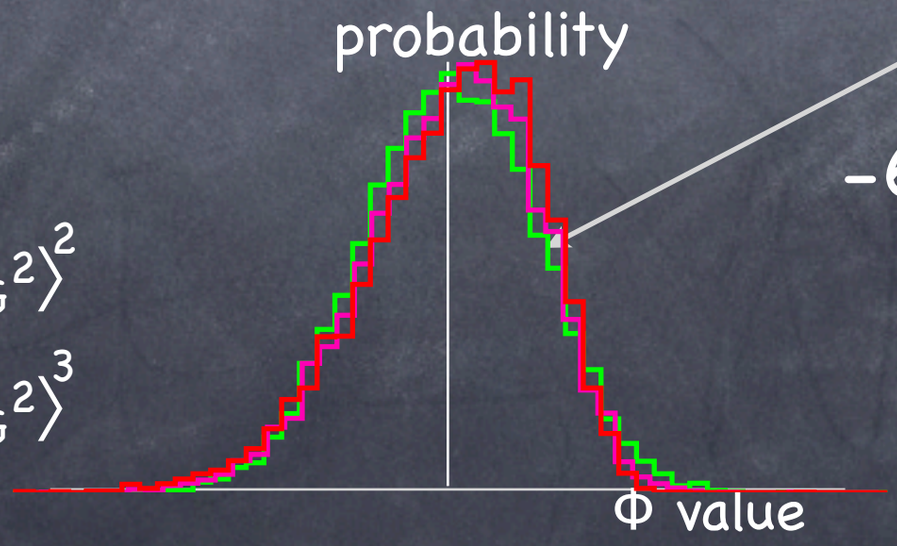


current constraints:

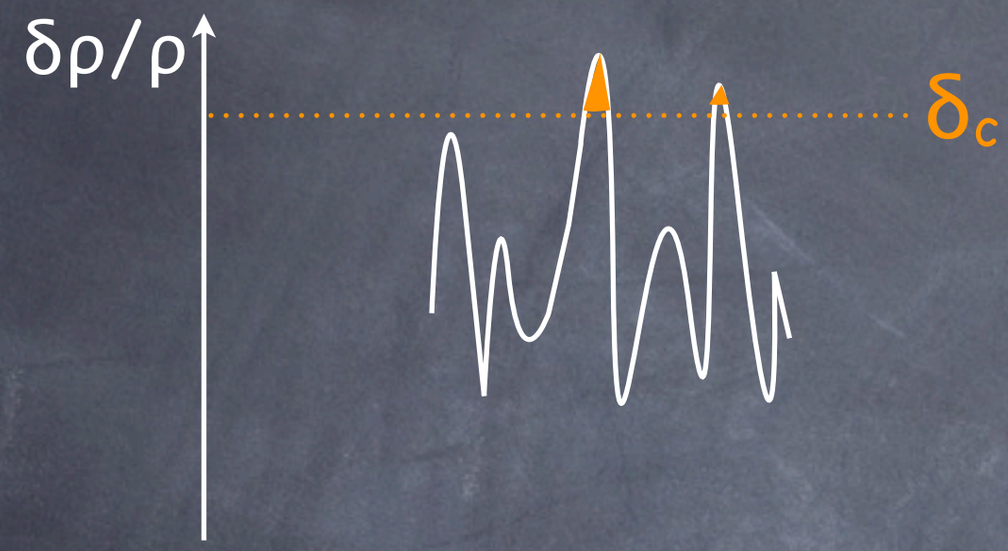
$-6000 < \tau_{NL} < 33{,}000$

(WMAP, Smidt et al 2010)

(Lyth and Wands 2002; Ichikawa, Suyama, Takahishi, Yamaguchi (2008); Tseliakhovich, Hirata, Slosar 2010; Shandera, Dalal, Huterer 2010)

A Signature: more/fewer massive halos

dark matter halos form in peaks of the density field



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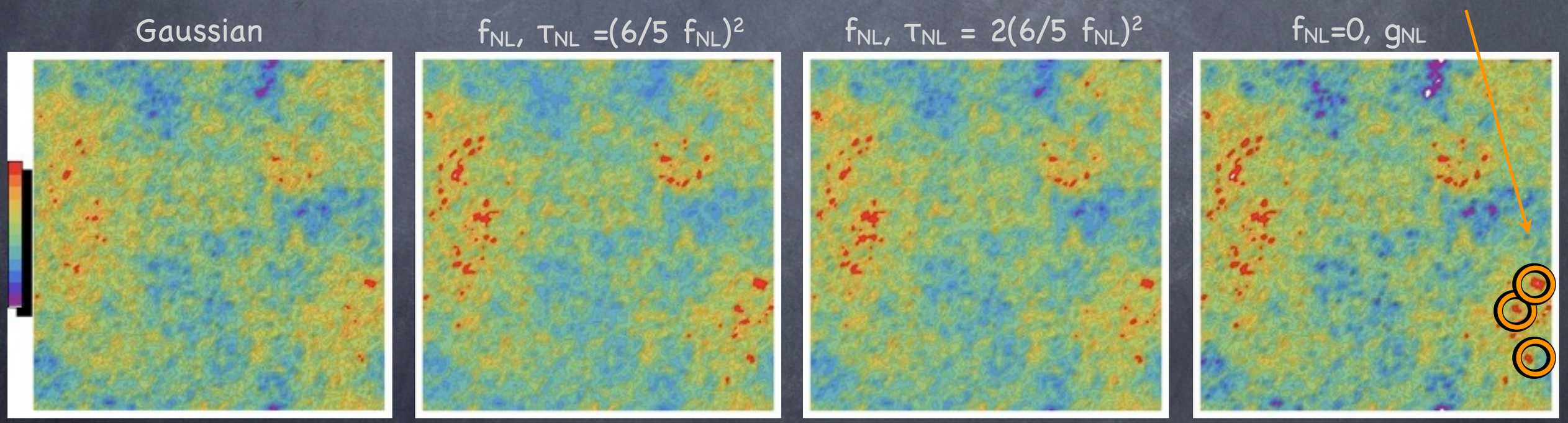
non-Gaussianity changes the number density of peaks



number of peaks ≅ number of halos

Lucchin & Matarrese 1988; Chiu, Ostriker, Strauss 1998;
Robinson, Gawiser, Silk 2000; Matarrese, Verde, Jimenez 2000

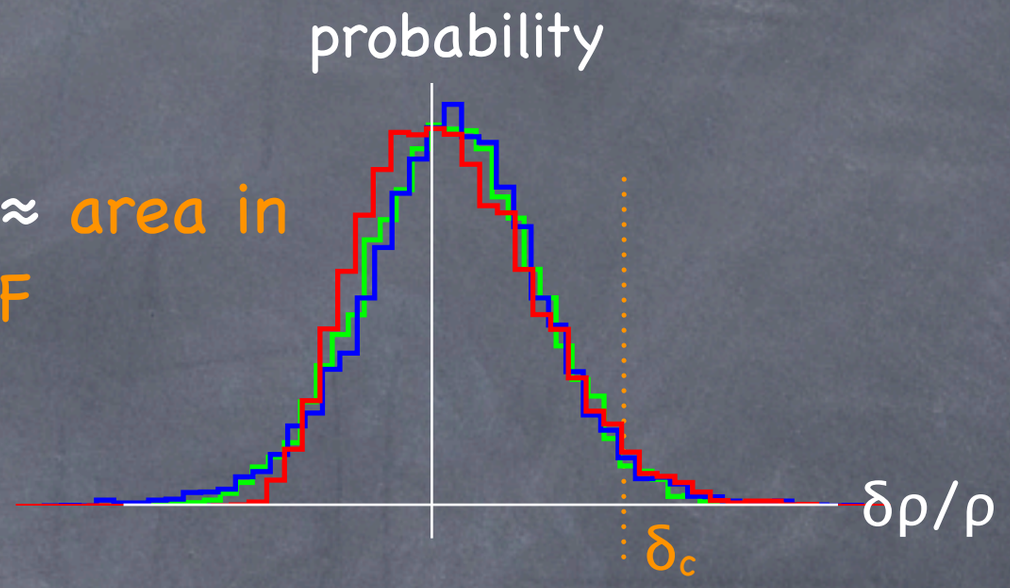
Simplest approach for analytic mass function

number of peaks ≅ number of halos

number of peaks ≈ area in tail of PDF

PDF for δ(M) ↔ # of halos of mass M

(Press & Schechter 1974)



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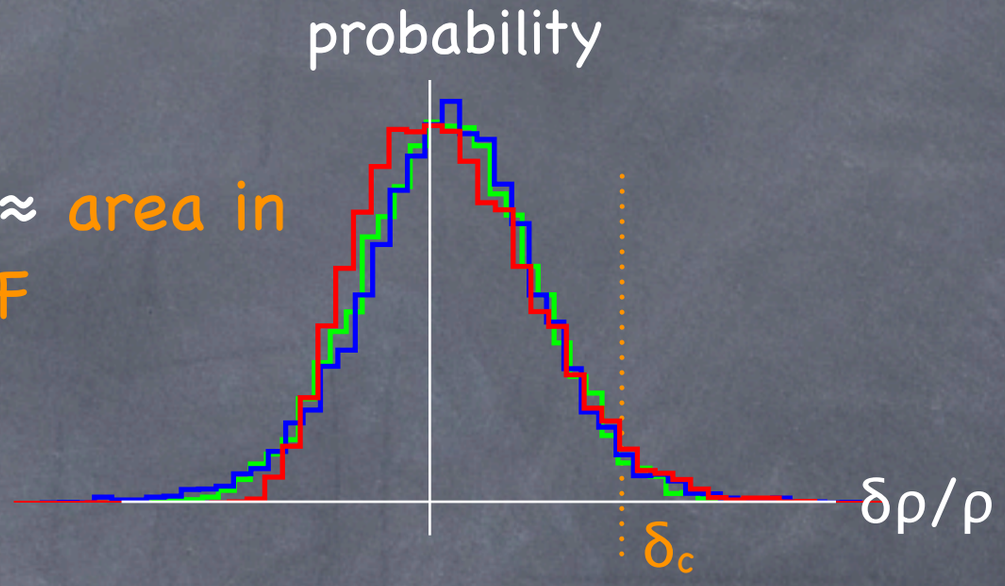

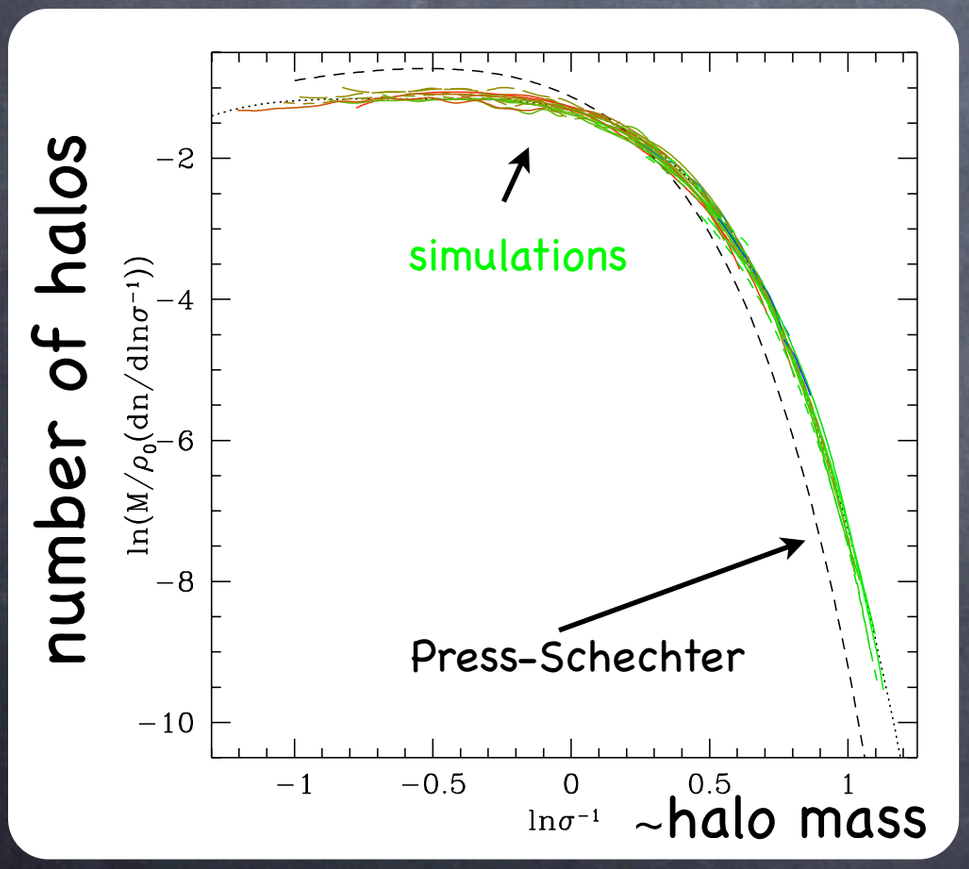

Jenkins et al 2000

only qualitative agreement for Gaussian cosmology

Lucchin & Matarrese 1988; Chiu, Ostriker, Strauss 1998; Robinson, Gawiser, Silk 2000; Matarrese, Verde, Jimenez 2000

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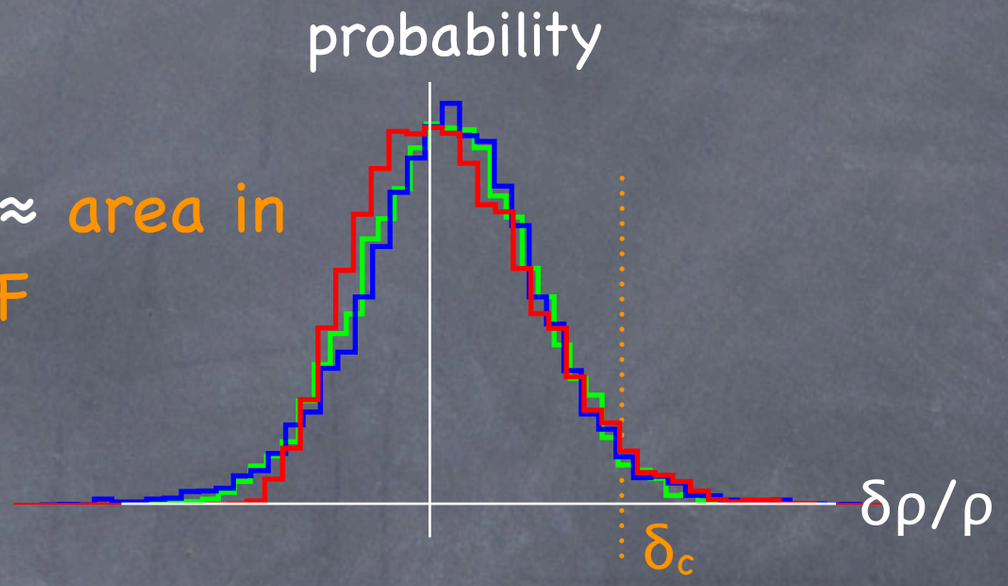
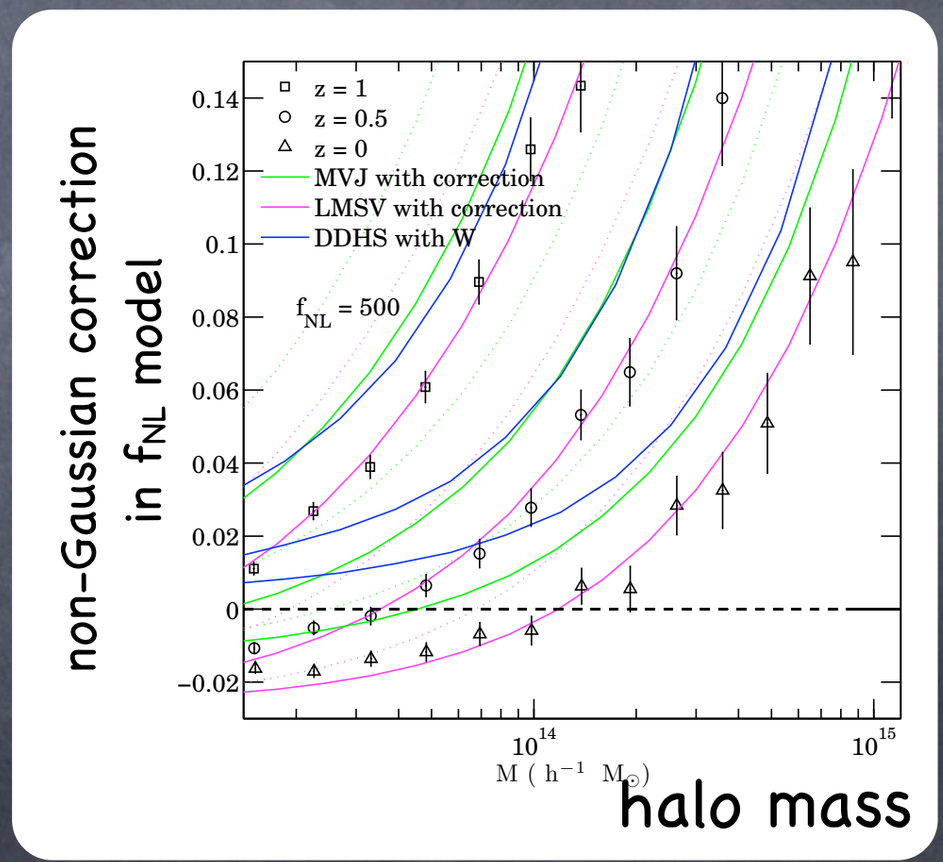


But seems to work OK for the non-Gaussian correction $n_{NG}(M)/n_G(M)$



Pillepich, Porciani, Hahn 2008 (and others)

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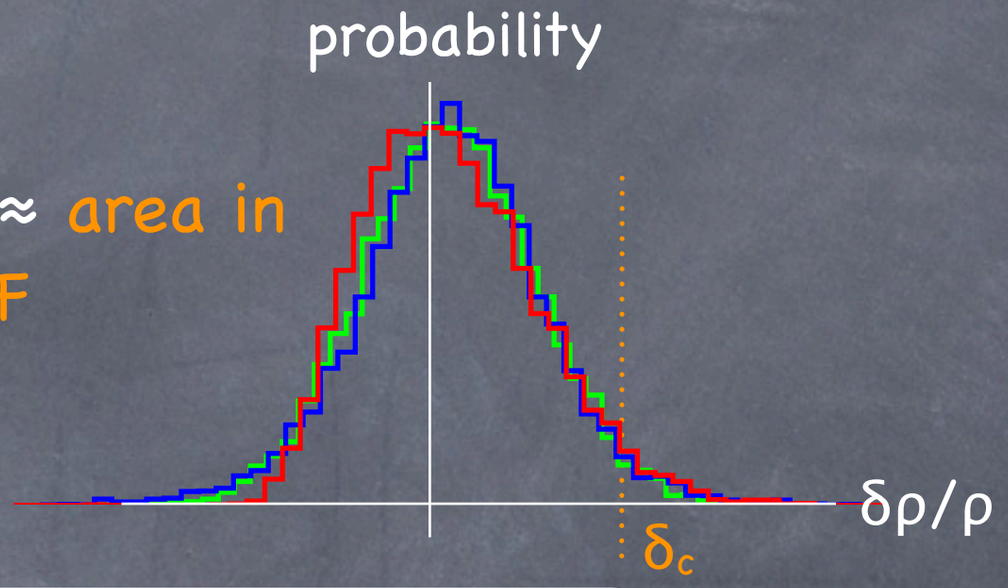

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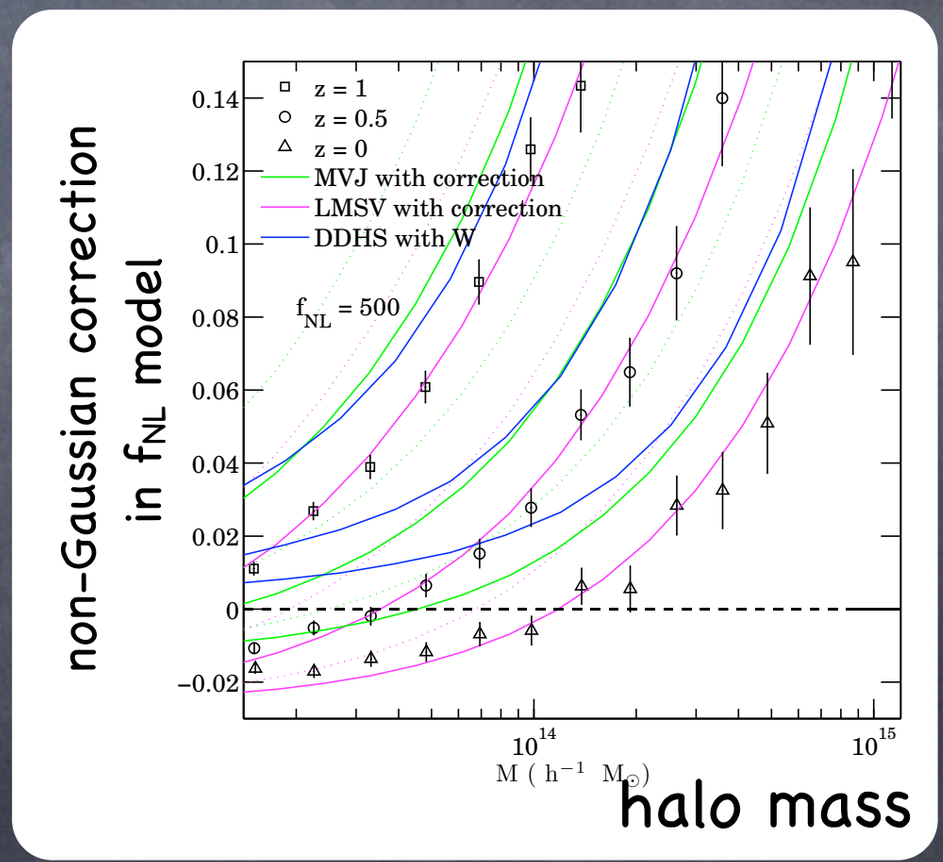
Of course we need simulations to trust this, and once we have them we can just fit for $n_{NG}(M)$



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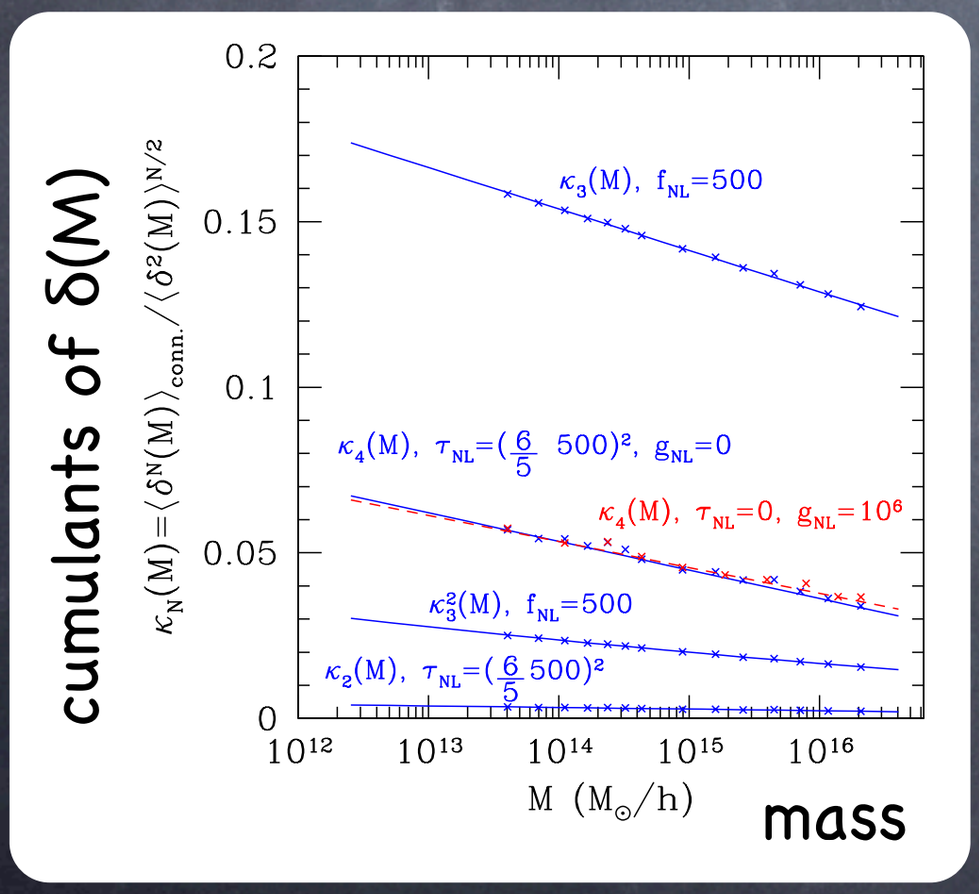

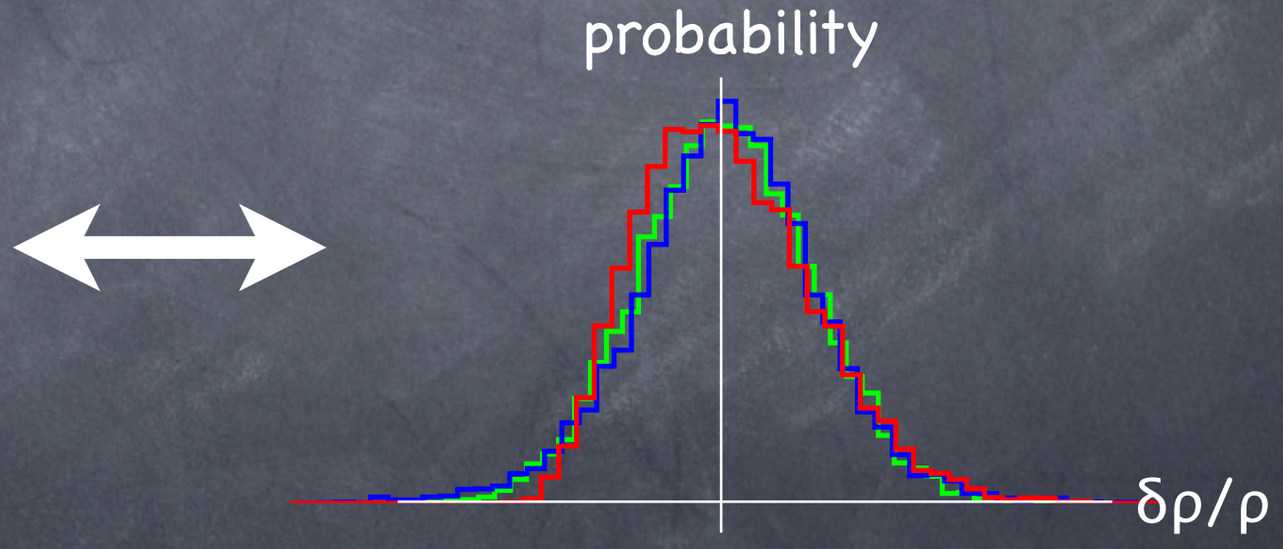

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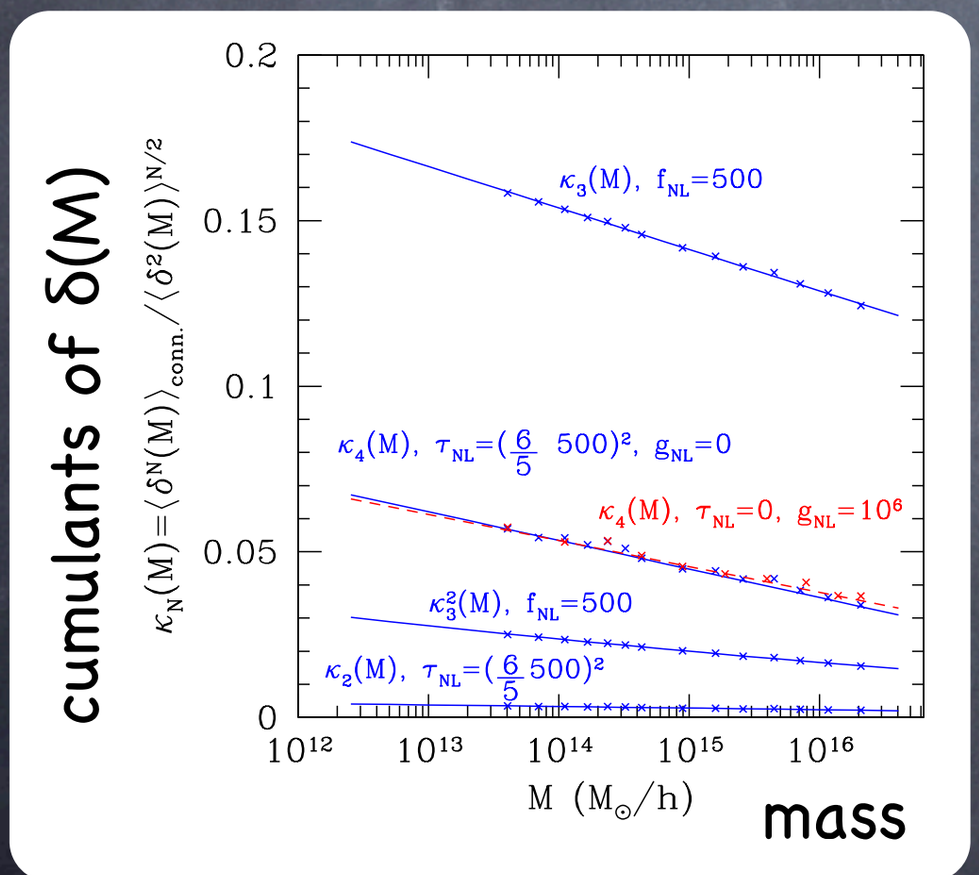

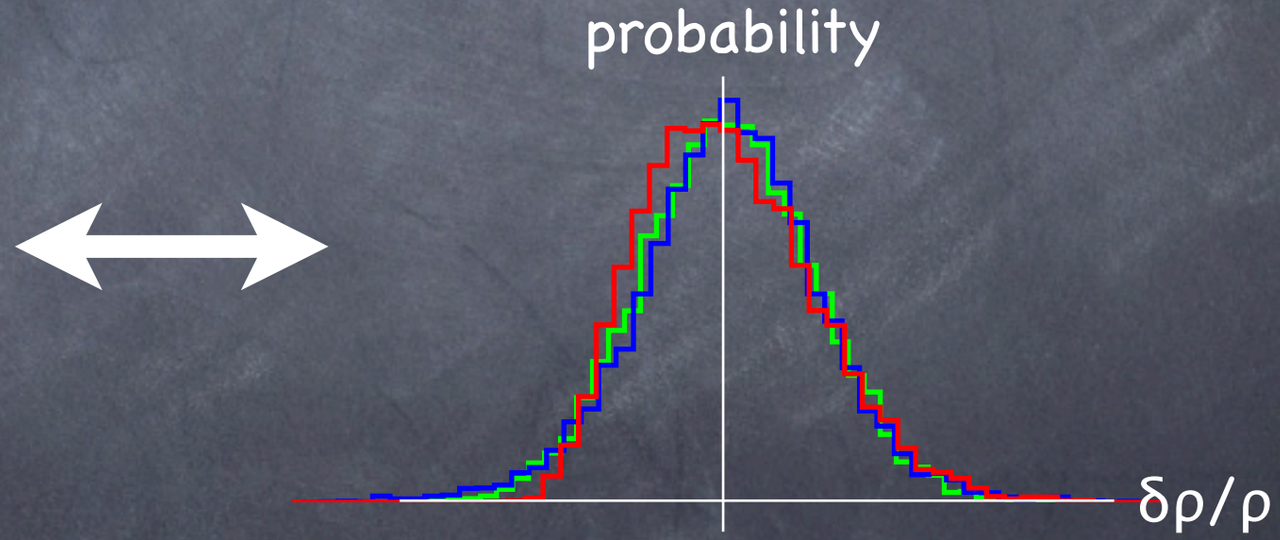

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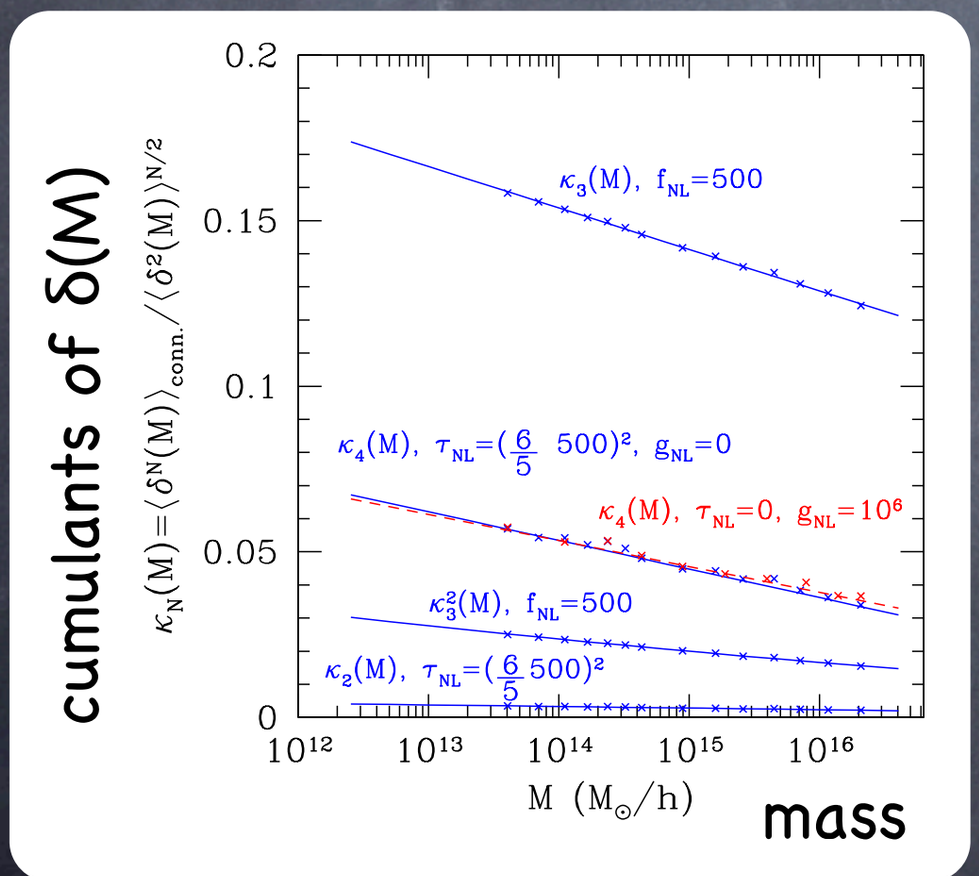

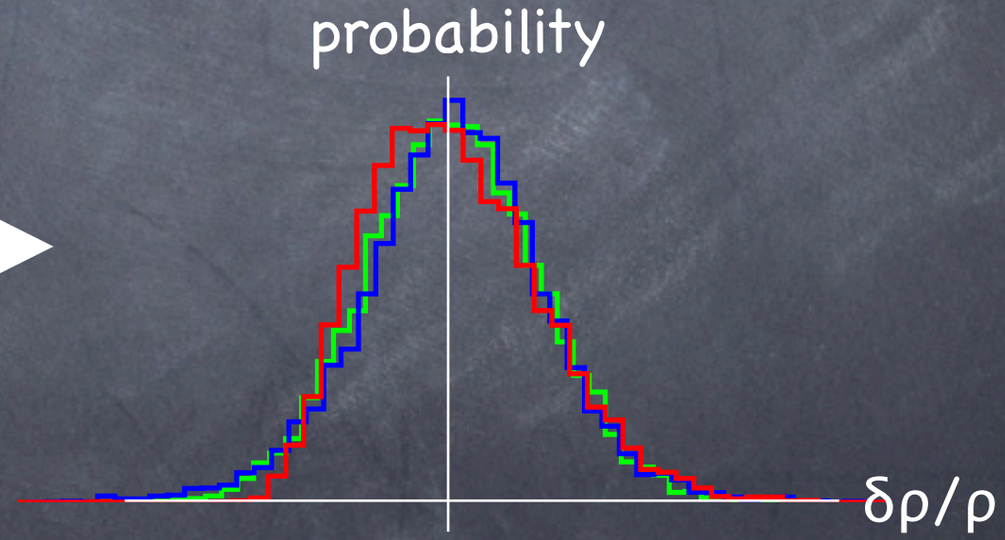

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(τ_{NL} terms log-divergent w/box size) Boubeker & Lyth 2005

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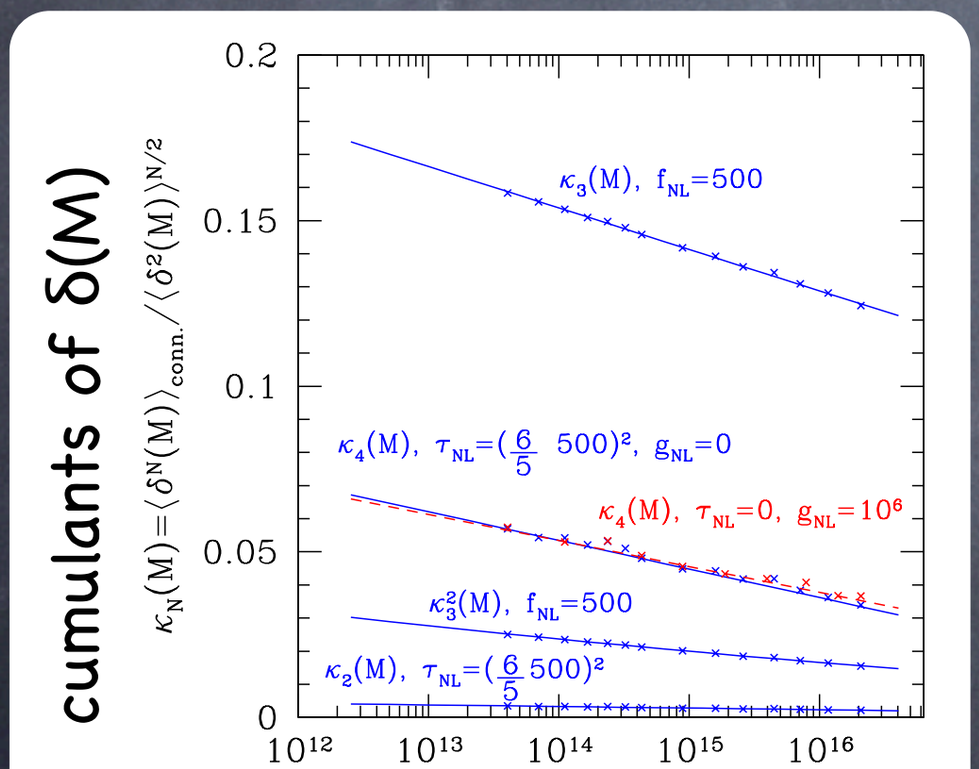
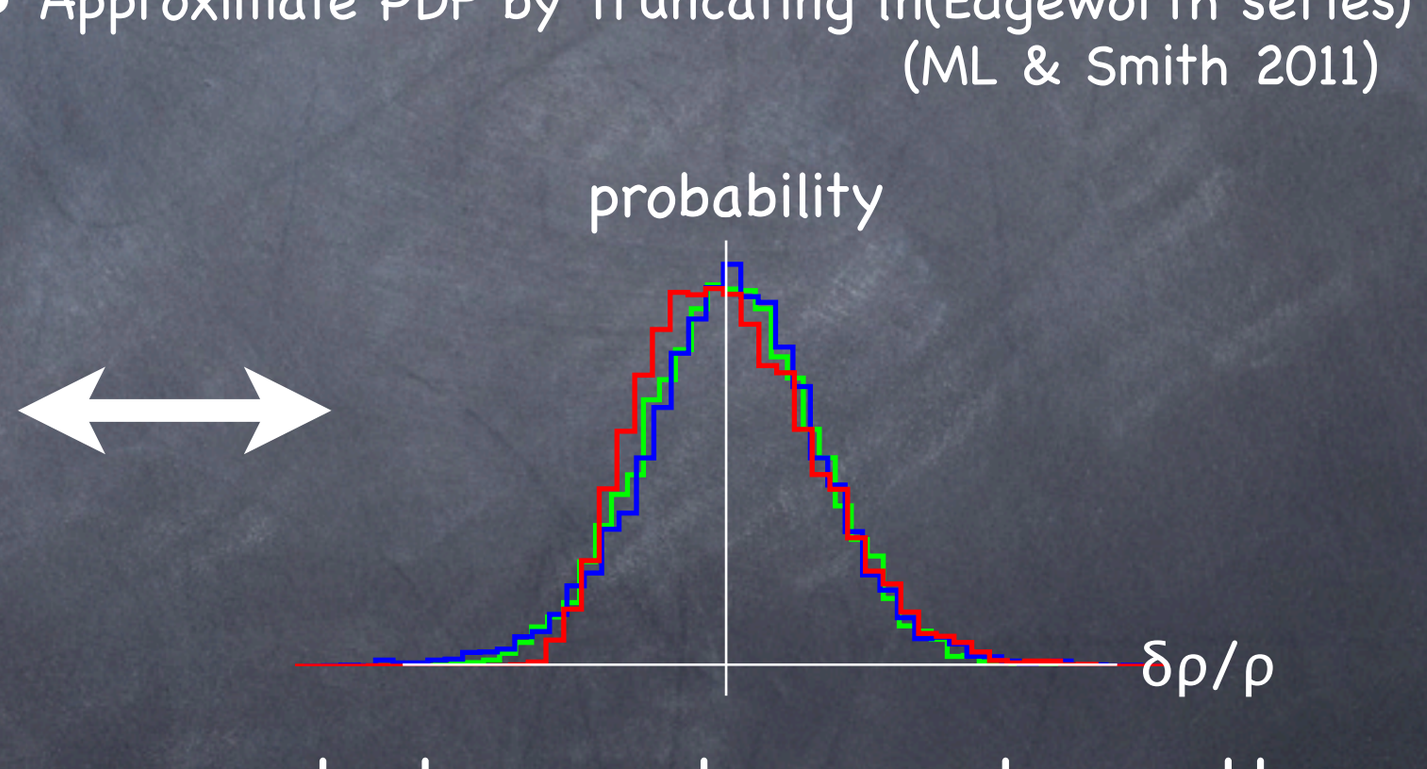


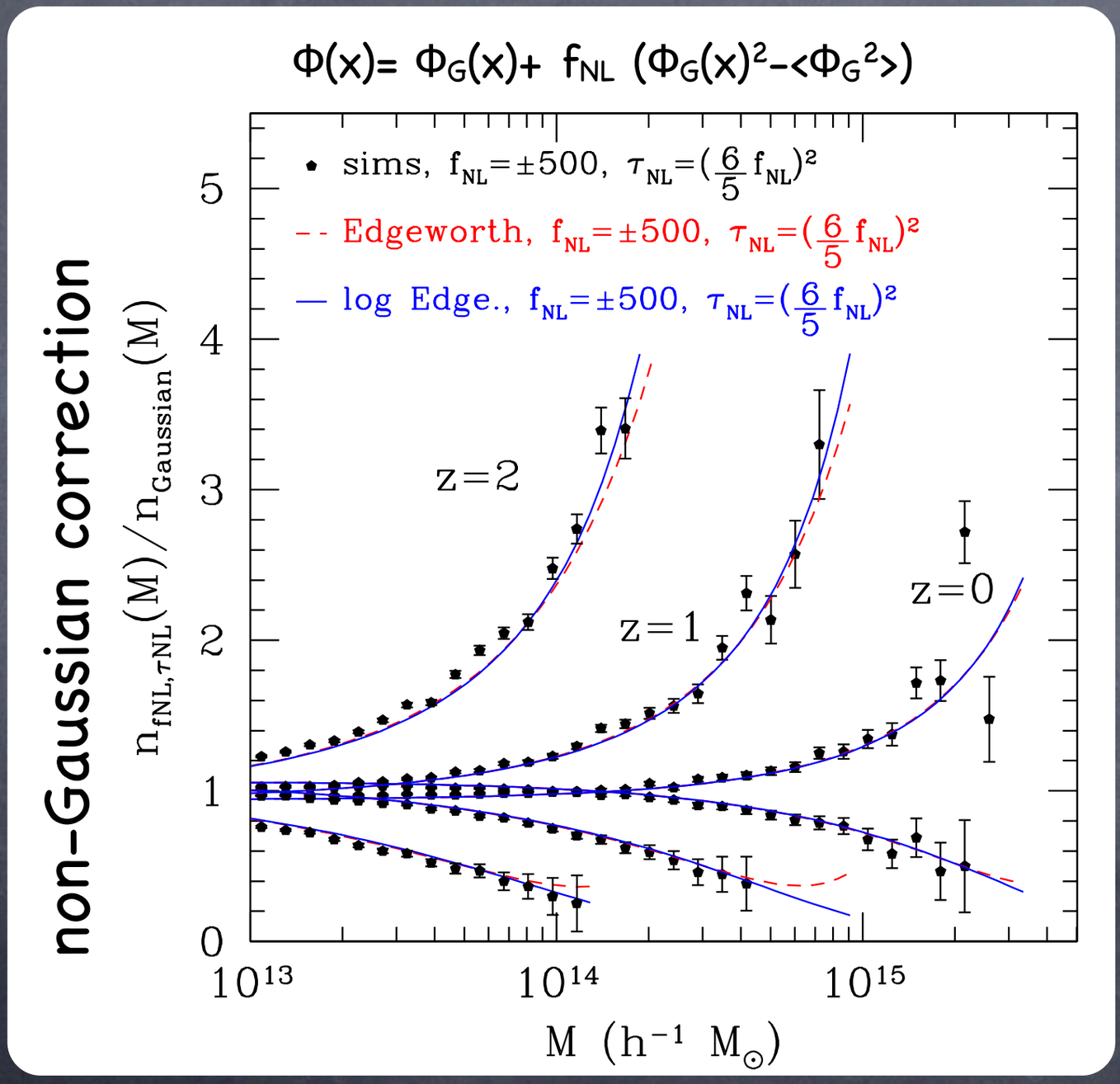


Beyond "Extended Press-Schechter": Lam & Sheth 2009; Maggiore & Riotto 2009; D'Amico, Musso, Norena, Paranjape 2010; Chongchitnan & Silk 2010; Yokoyama, Sugiyama, Zaroubi, Silk 2011

A Signature: more/fewer massive halos

N-body simulations with f_{NL}, g_{NL}, and τ_{NL}

f_{NL}



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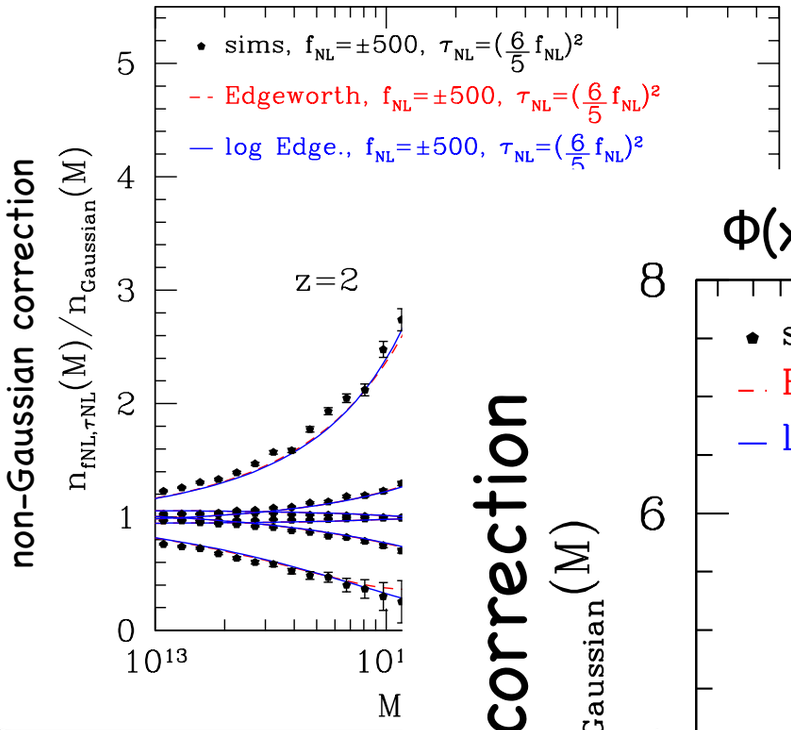
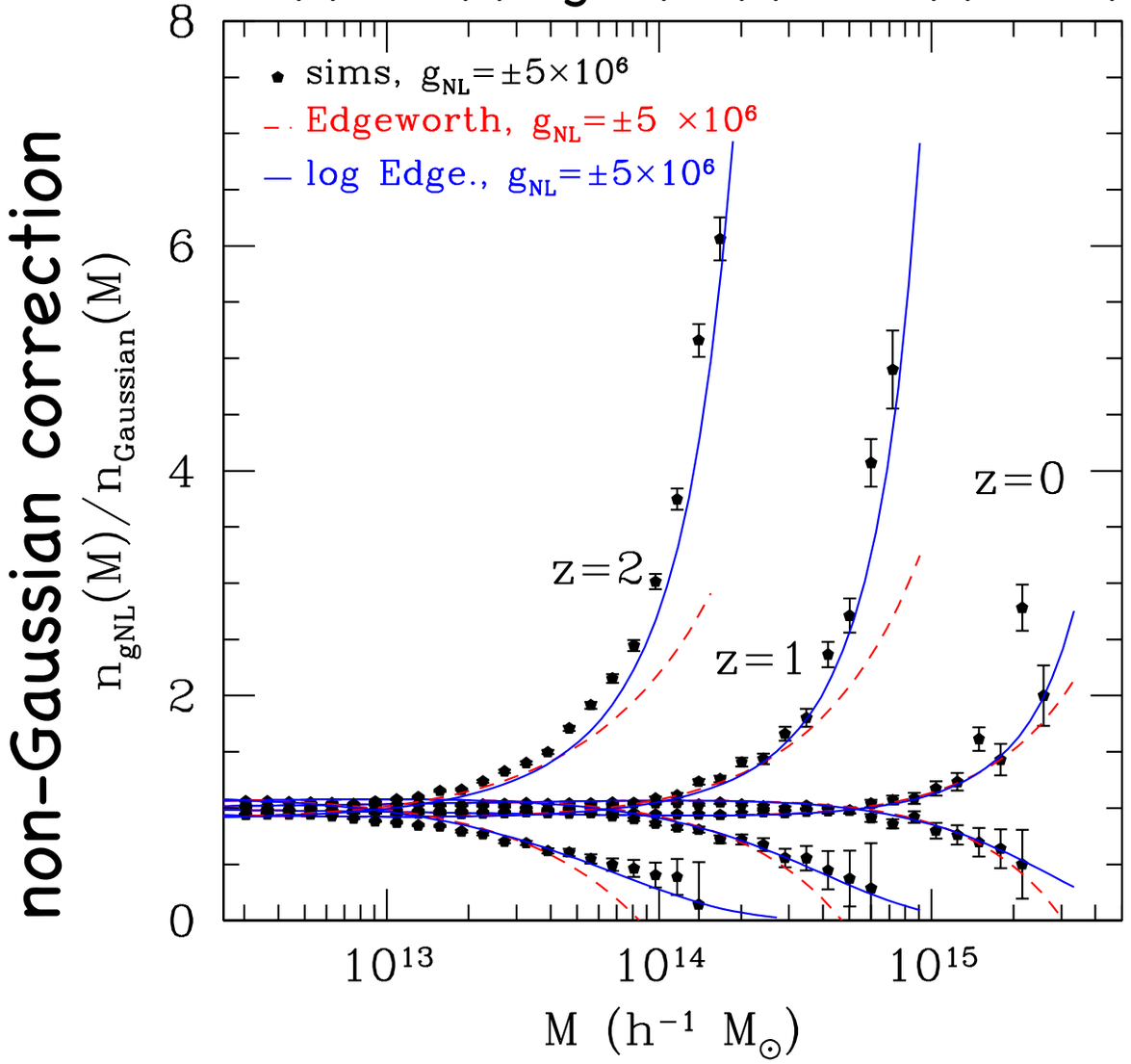


$\Phi(x)= \Phi_G(x)+ g_{NL} (\Phi_G(x)^3-3\Phi_G(x)\langle\Phi_G^2\rangle)$?



g_{NL}

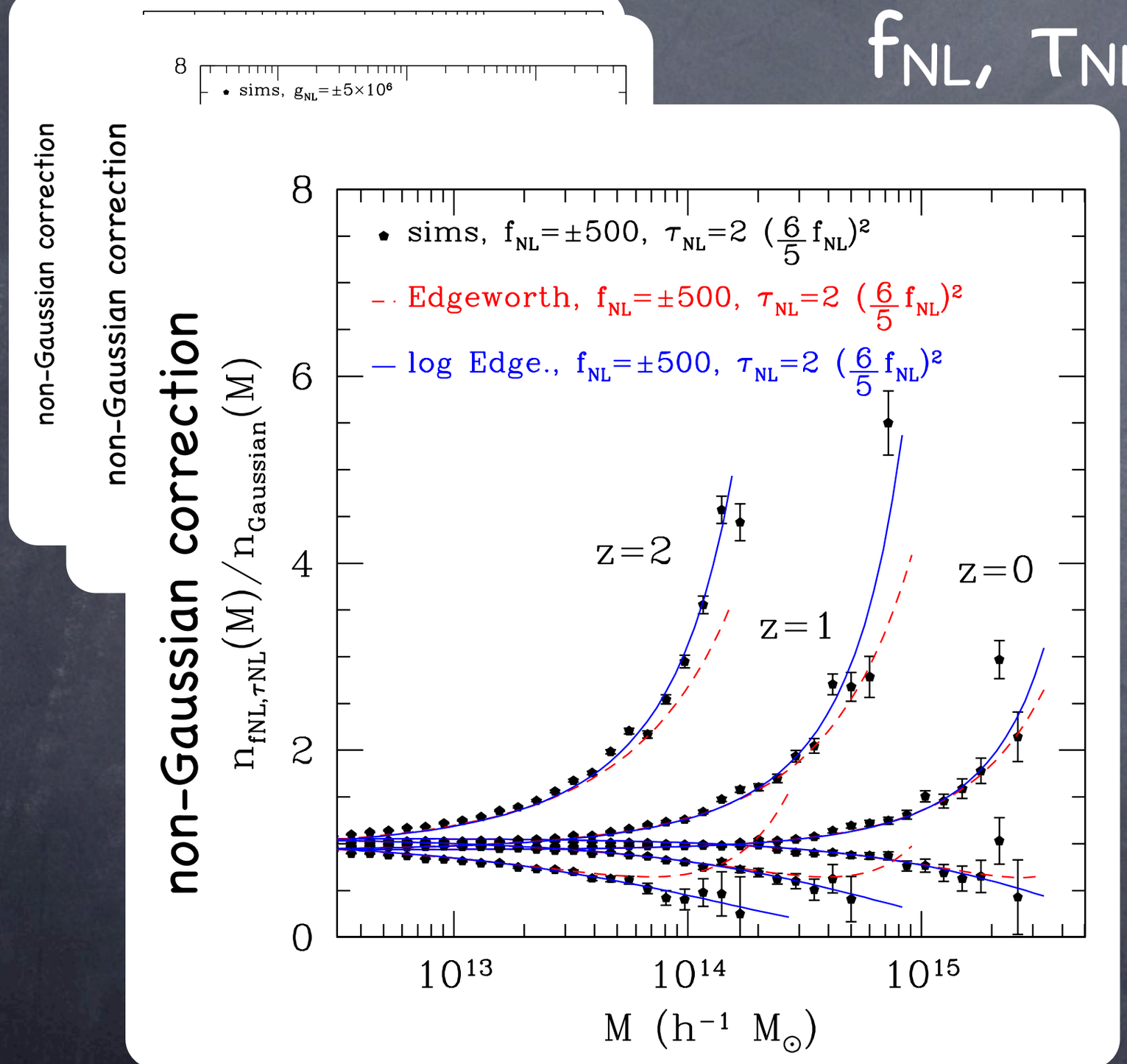
kurtosis can have important effects on the mass function!

(see also Desjacques and Seljak 2010)

A Signature: more/fewer massive halos

N-body simulations with f_{NL}, g_{NL}, and τ_{NL}

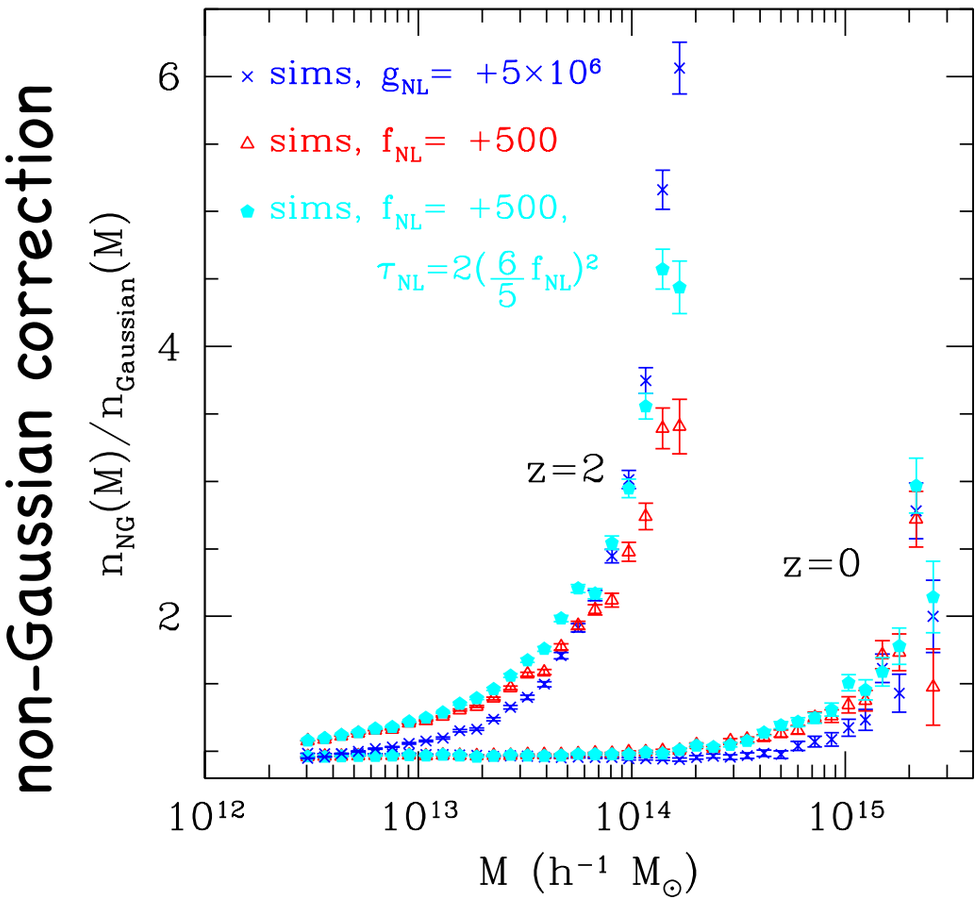
f_{NL}, τ_{NL} independent

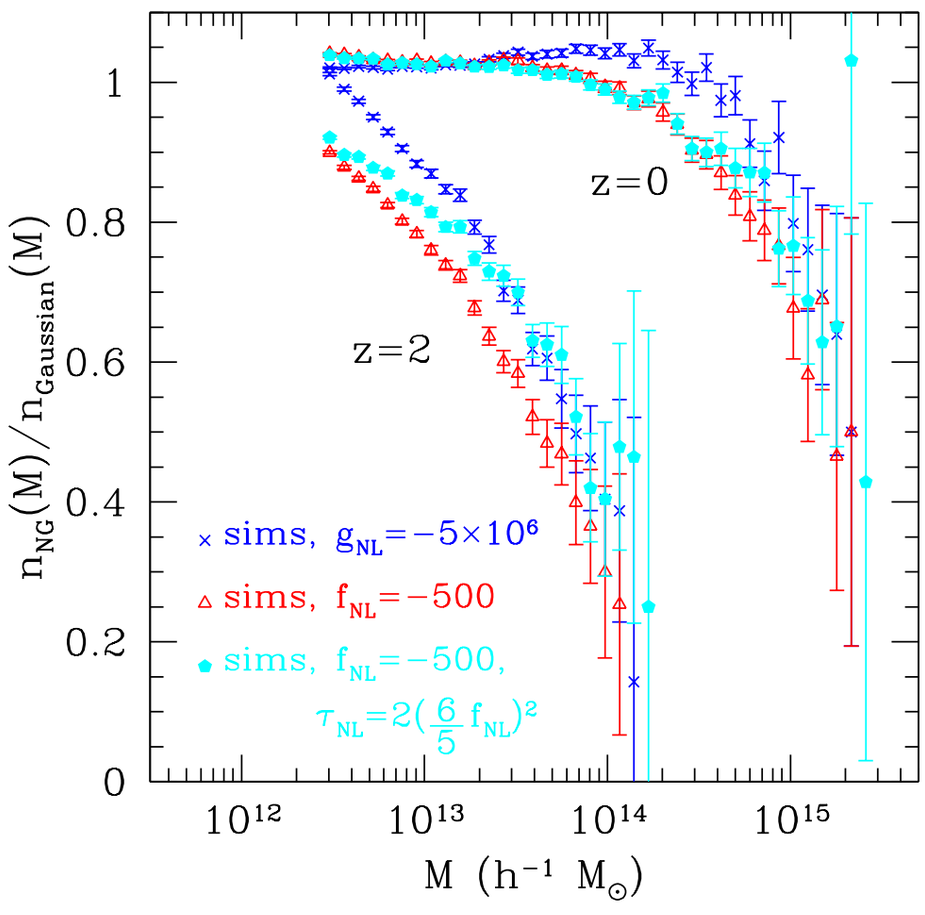


$\tau_{NL} \neq (5/6 f_{NL})^2$
is noticeable!

A Signature: more/fewer massive halos

comparison of f_{NL}, g_{NL}, and τ_{NL}





τ_{NL} looks like f_{NL} with larger f_{NL}

g_{NL} looks a little different

Summary

- f_{NL}, g_{NL} and τ_{NL} non-Gaussian initial conditions can significantly change the abundance of dark matter halos
- We've found an analytic description for the change to the halo mass function that compares well to N-body for f_{NL}, g_{NL} and τ_{NL} -- perhaps it works for more general forms of NG?

See also Sugiyama's talk!