Primordial Non-Gaussianity in the Halo Mass Function

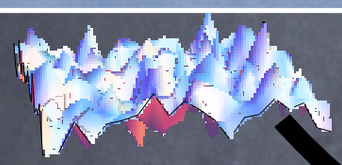
g_{NL} and τ_{NL}!

Marilena LoVerde (Institute for Advanced Study)
with Kendrick Smith (Princeton University)

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

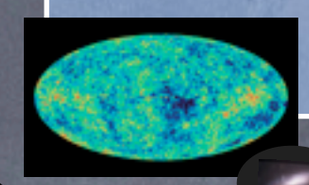
The Big Picture:

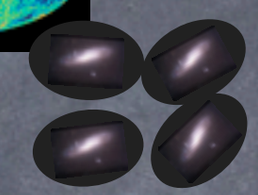
inflationary perturbations



time + gravity

stuff in the late universe: CMB galaxies, clusters of galaxies





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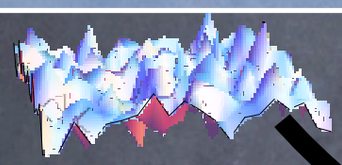

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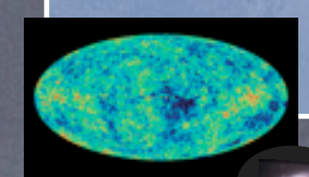

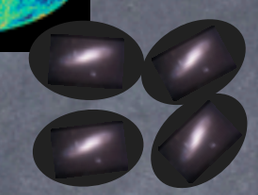

Fact: linear evolution preserves the statistics of the perturbations

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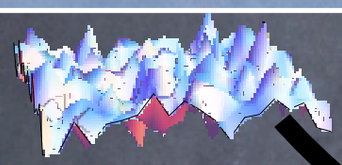

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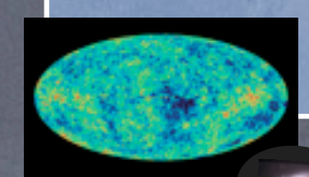
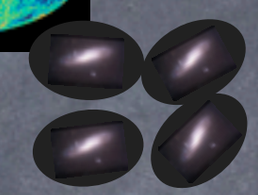


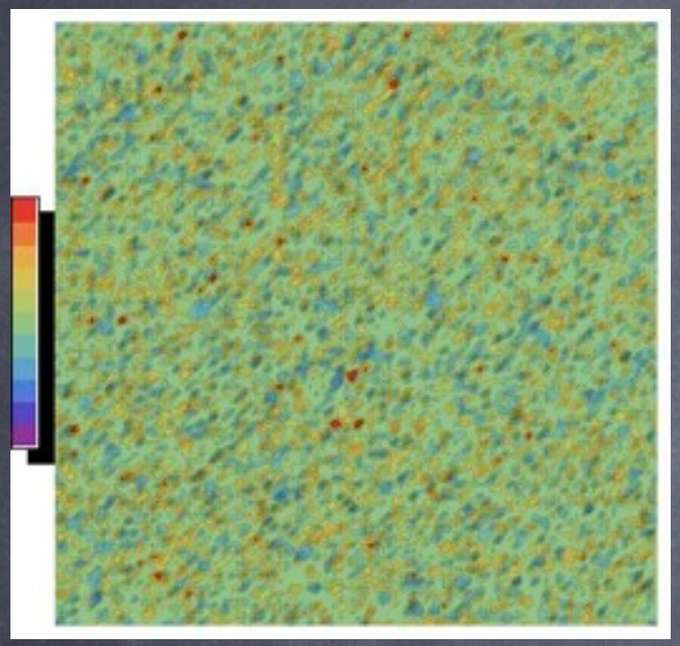


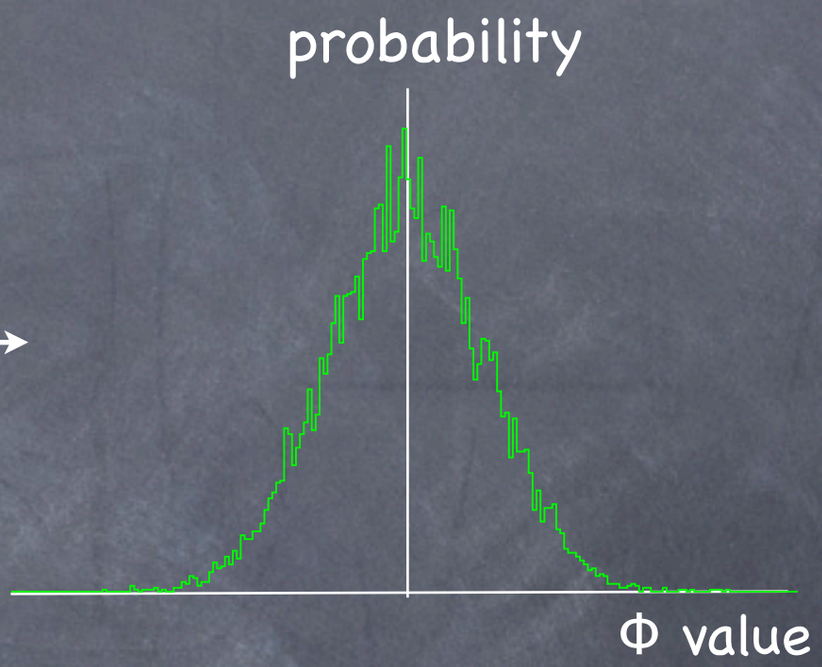
Fact: linear evolution preserves the statistics of the perturbations

Fact: inflationary models can make different predictions for the statistical distribution of density perturbations

Statistics of perturbations?

a Gaussian random field, Φ





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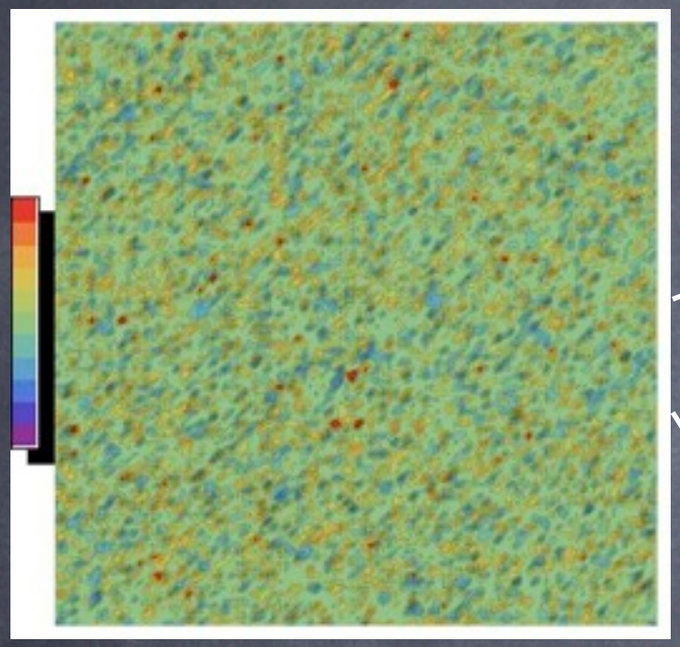
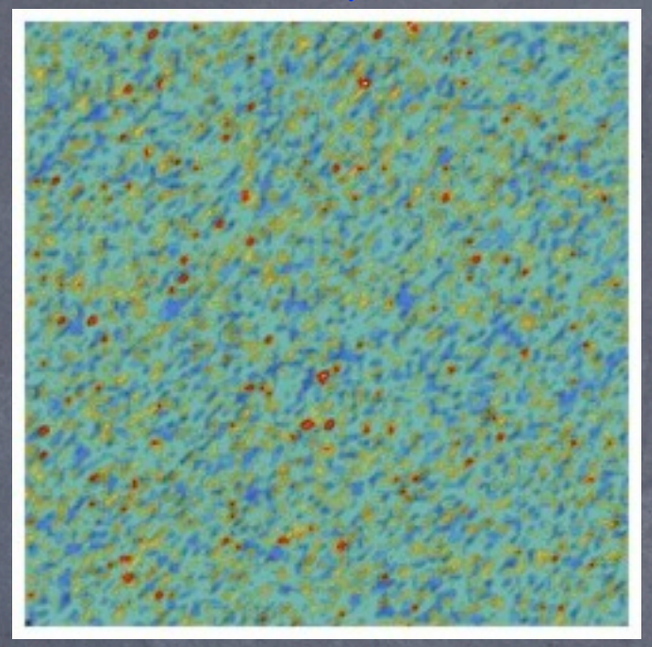


same variance, positive skewness



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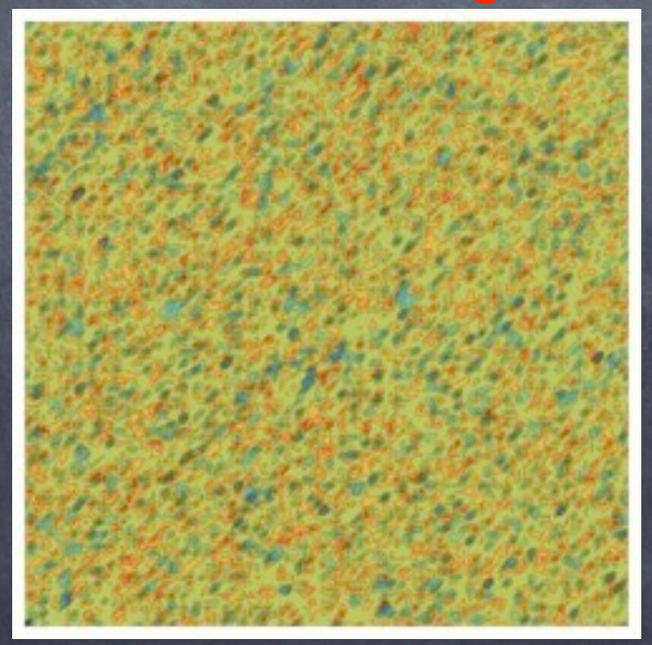
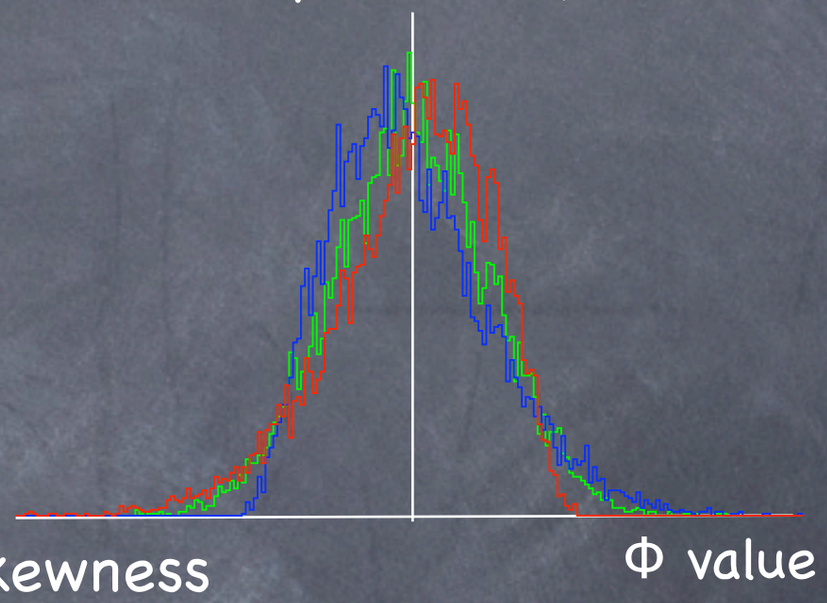




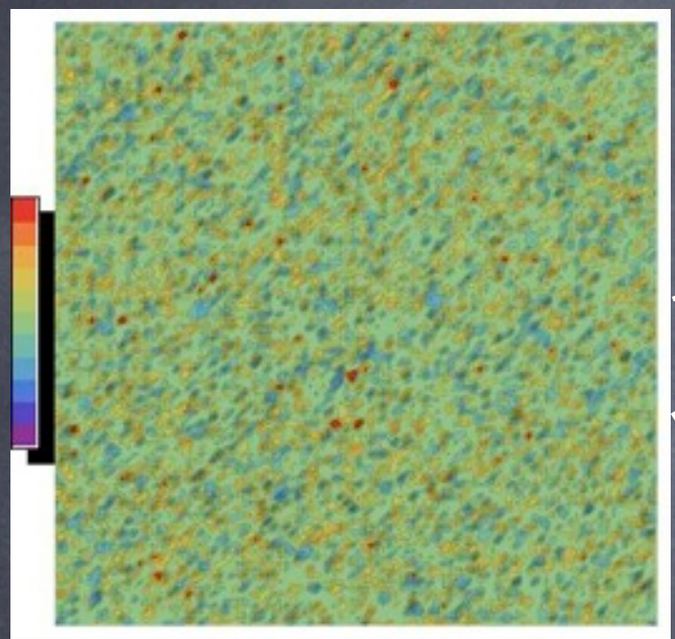
$$\Phi=\Phi_G + f_{NL} (\Phi_G^2-\langle\Phi_G^2\rangle)$$

(Φ=primordial gravitational potential)

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

Statistics of perturbations?

a Gaussian random field, Φ



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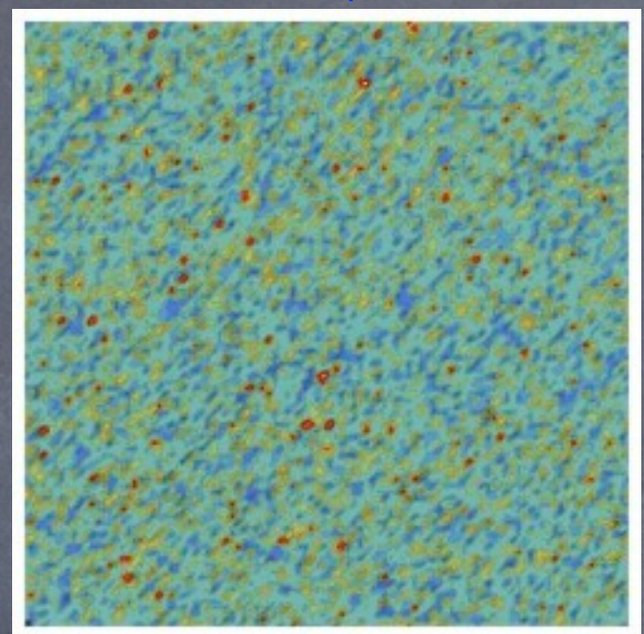

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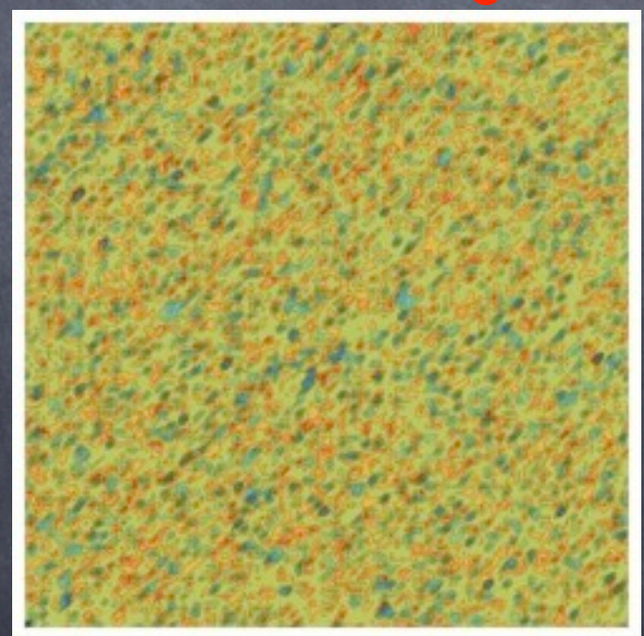
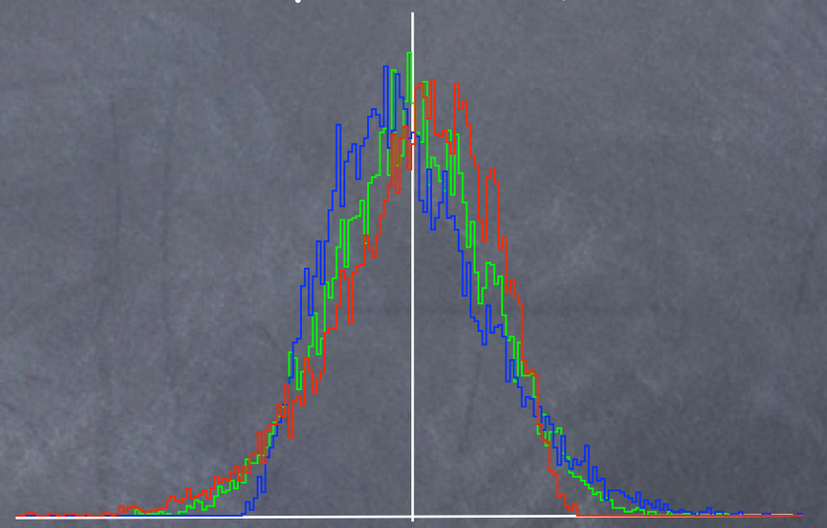




$$\Phi=\Phi_G + f_{NL} (\Phi_G^2-\langle\Phi_G^2\rangle)$$

(Φ=primordial gravitational potential)

current constraints:
$-10 < f_{NL} < 74$

(WMAP, Komatsu et al 2010)

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

what about

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

(see e.g. Okamoto and Hu 2002; Enqvist and Nurmi 2005)

Or

$$\Phi = \Psi_G + \Phi_G + f_{NL}\,(\Phi_G^2 - \langle\Phi_G^2\rangle)\ ? \qquad \text{“}\tau_{NL}\text{”}$$

(see e.g. Lyth and Wands 2002; Tseliakhovich, Hirata, Slosar 2010)

(kurtosis can be important for both)

g_{NL} and no f_{NL} can arise in curvaton model w non/quadratic potential

τ_{NL} if significant curvaton <u>and</u> inflaton perturbations

current constraints: $-1{,}240{,}000 < g_{NL} < 1{,}560{,}000$ (WMAP data, Fergusson et al 2010)

$-6{,}100 < \tau_{NL} < 31{,}000$ (WMAP data, Smidt et al 2010)

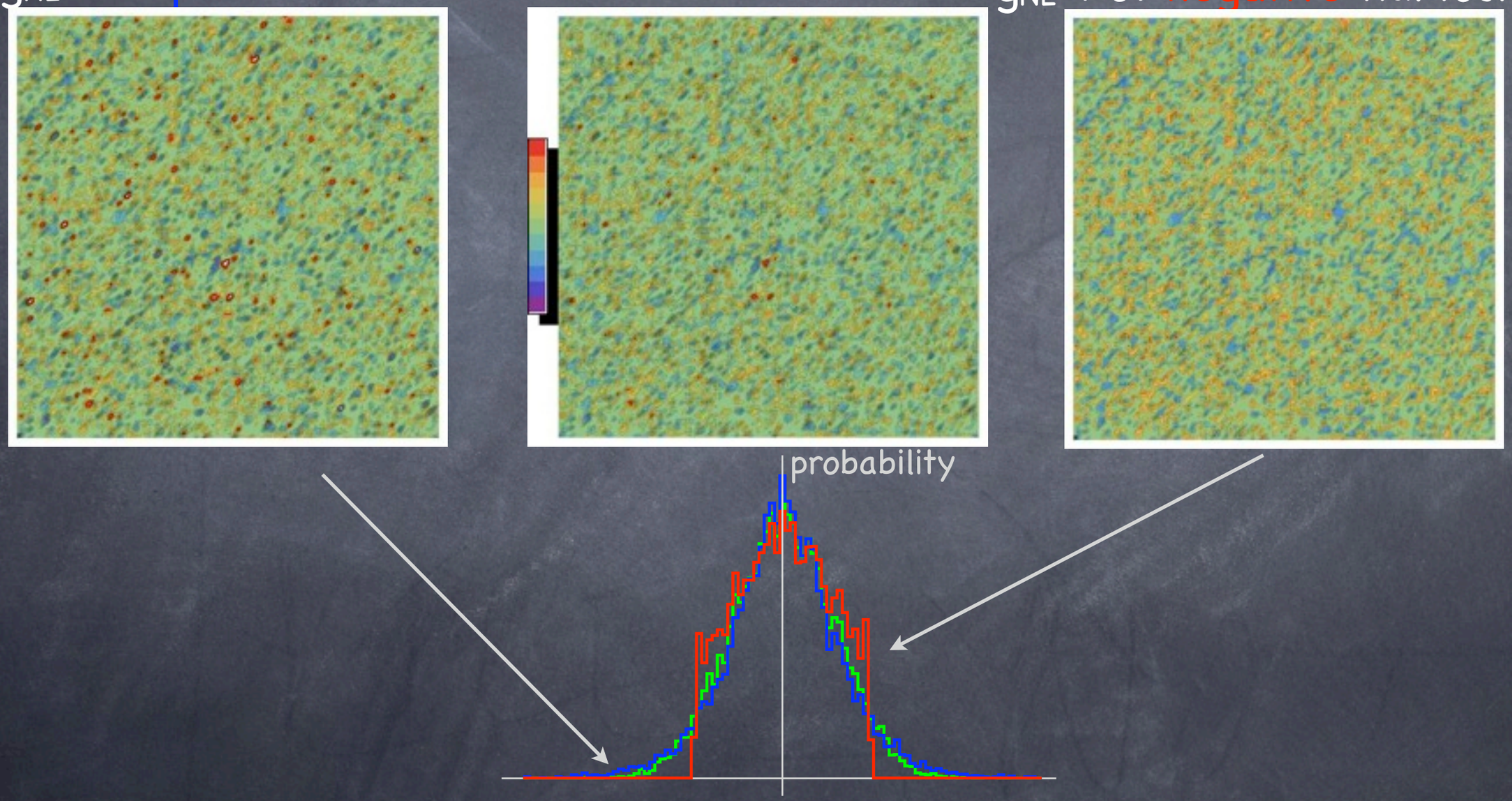
what about

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

$g_{NL} > 0$: positive kurtosis

Gaussian

$g_{NL} < 0$: negative kurtosis

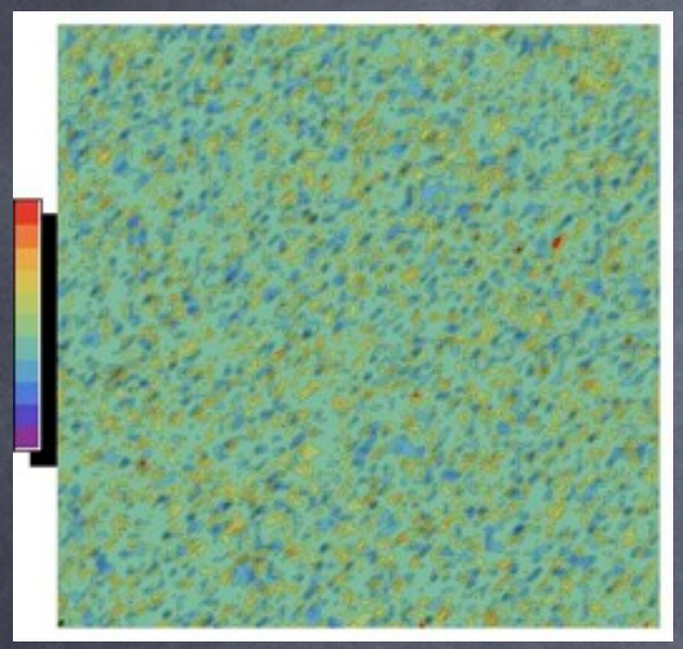


(Okamoto and Hu 2002; Enqvist and Nurmi 2005)

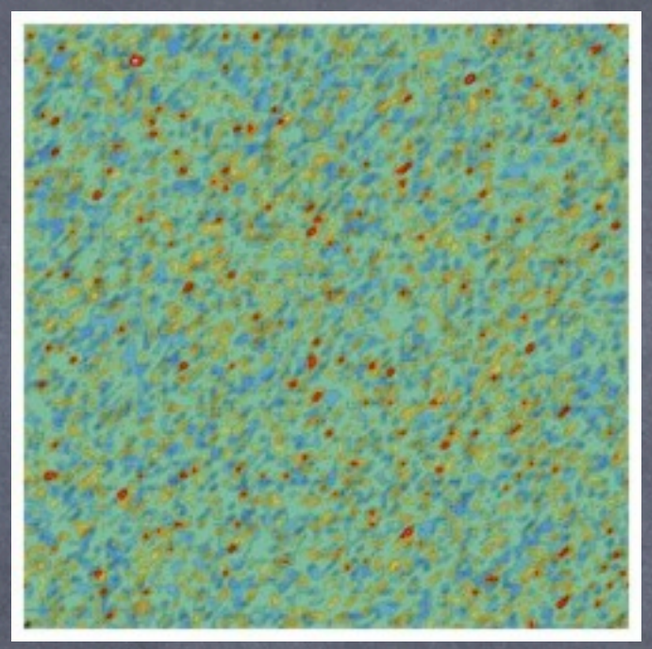
what about

$$\Phi = \Psi_G + \Phi_G + f_{NL}\,(\Phi_G^2 - \langle\Phi_G^2\rangle)\ ? \quad \text{“}\tau_{NL}\text{”}$$

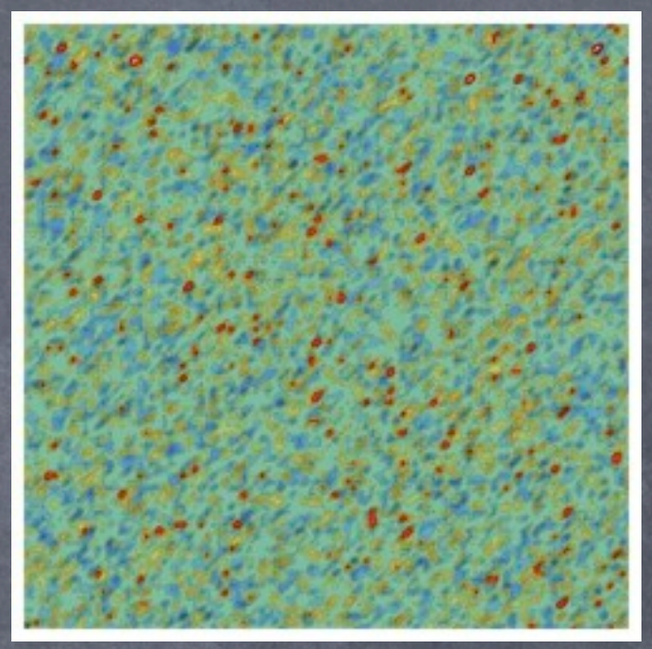
Gaussian

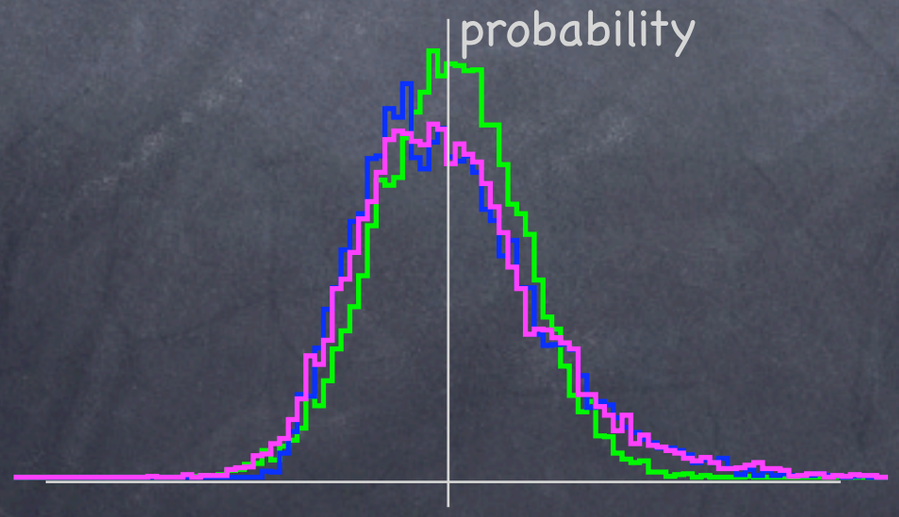


positive skewness and usual kurtosis: $\tau_{NL} = (6/5\ f_{NL})^2$



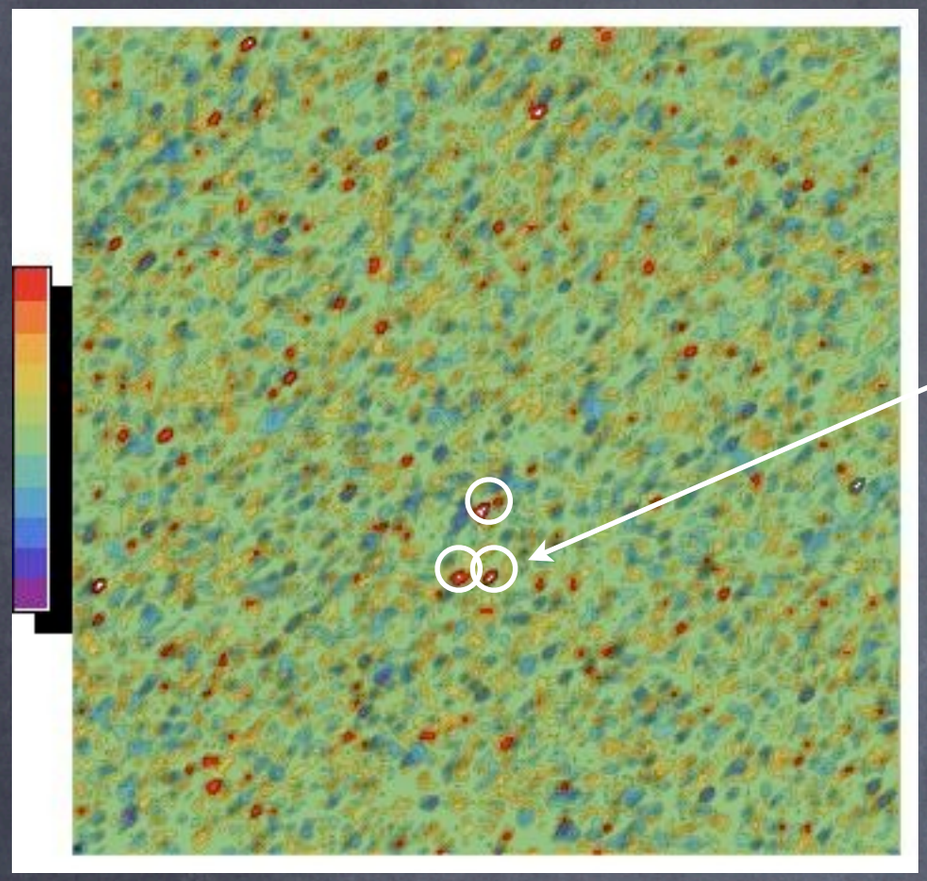
positive skewness and larger kurtosis: $\tau_{NL} > (6/5\ f_{NL})^2$





(Lyth and Wands 2002; Tseliakhovich, Hirata, Slosar 2010)

Non-Gaussianity affects the abundance of dark matter halos

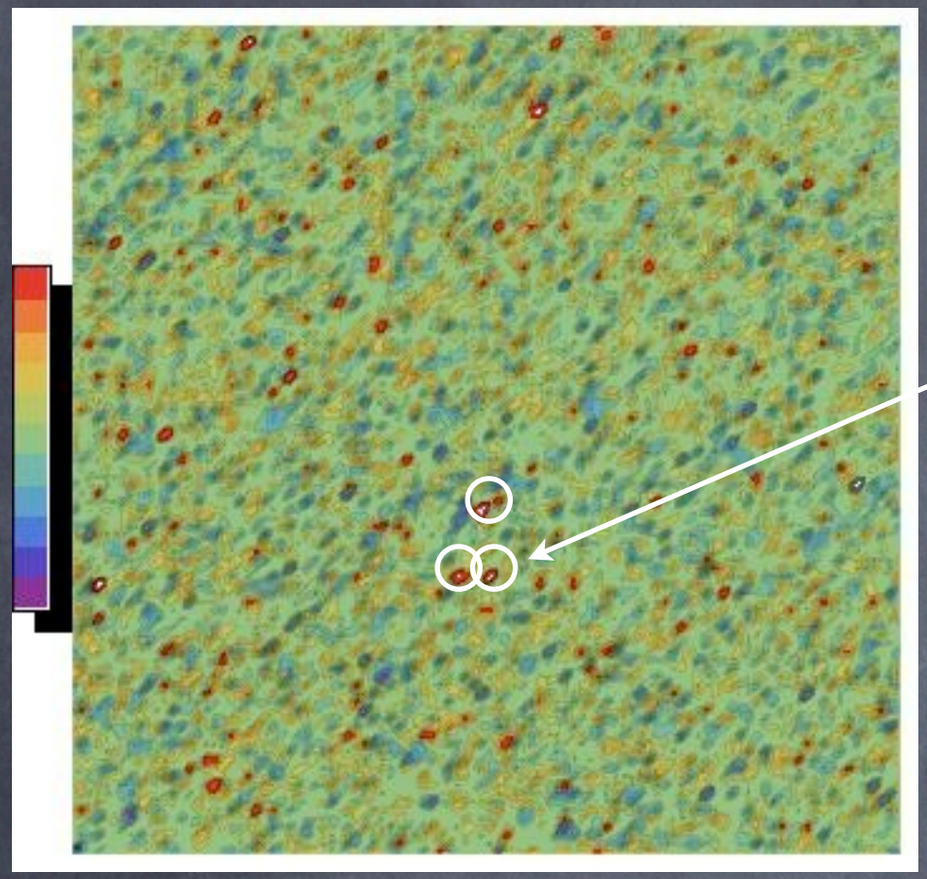


more extremely overdense regions --> more halos later

($g_{NL} > 0$)

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

Non-Gaussianity affects the abundance of dark matter halos



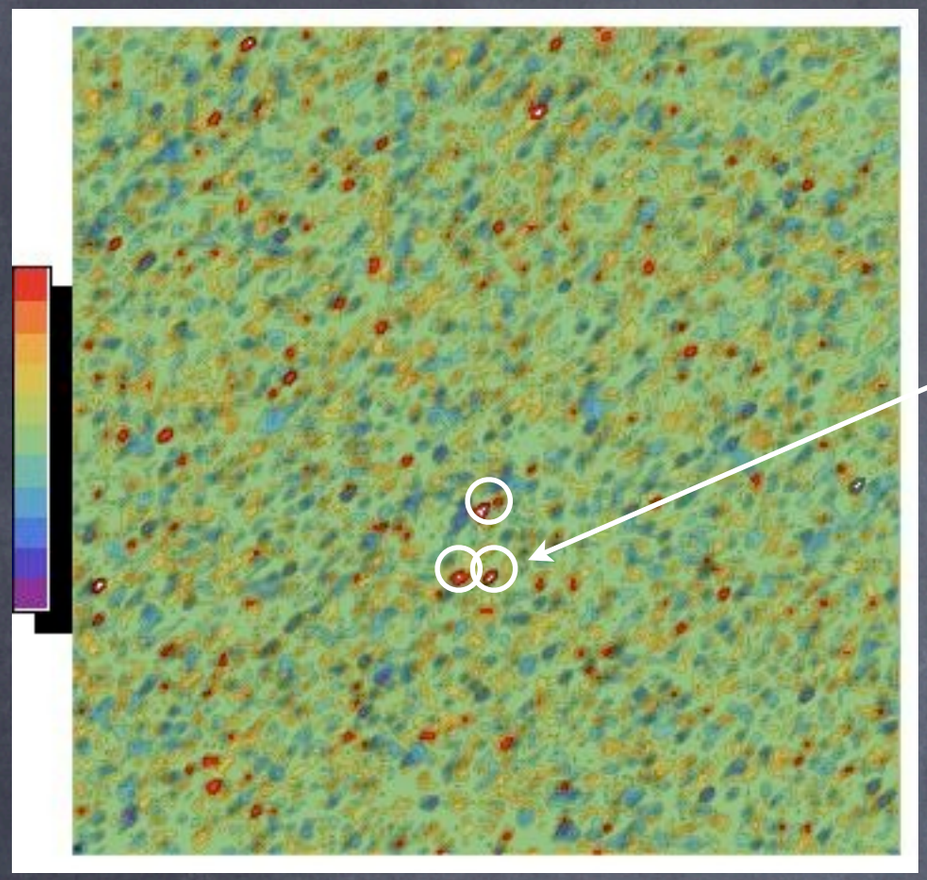
($g_{NL} > 0$)

more extremely overdense regions --> more halos later

Halo formation is complicated! Need to run N-body simulations to have accurate picture of consequences of primordial non-Gaussianity

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

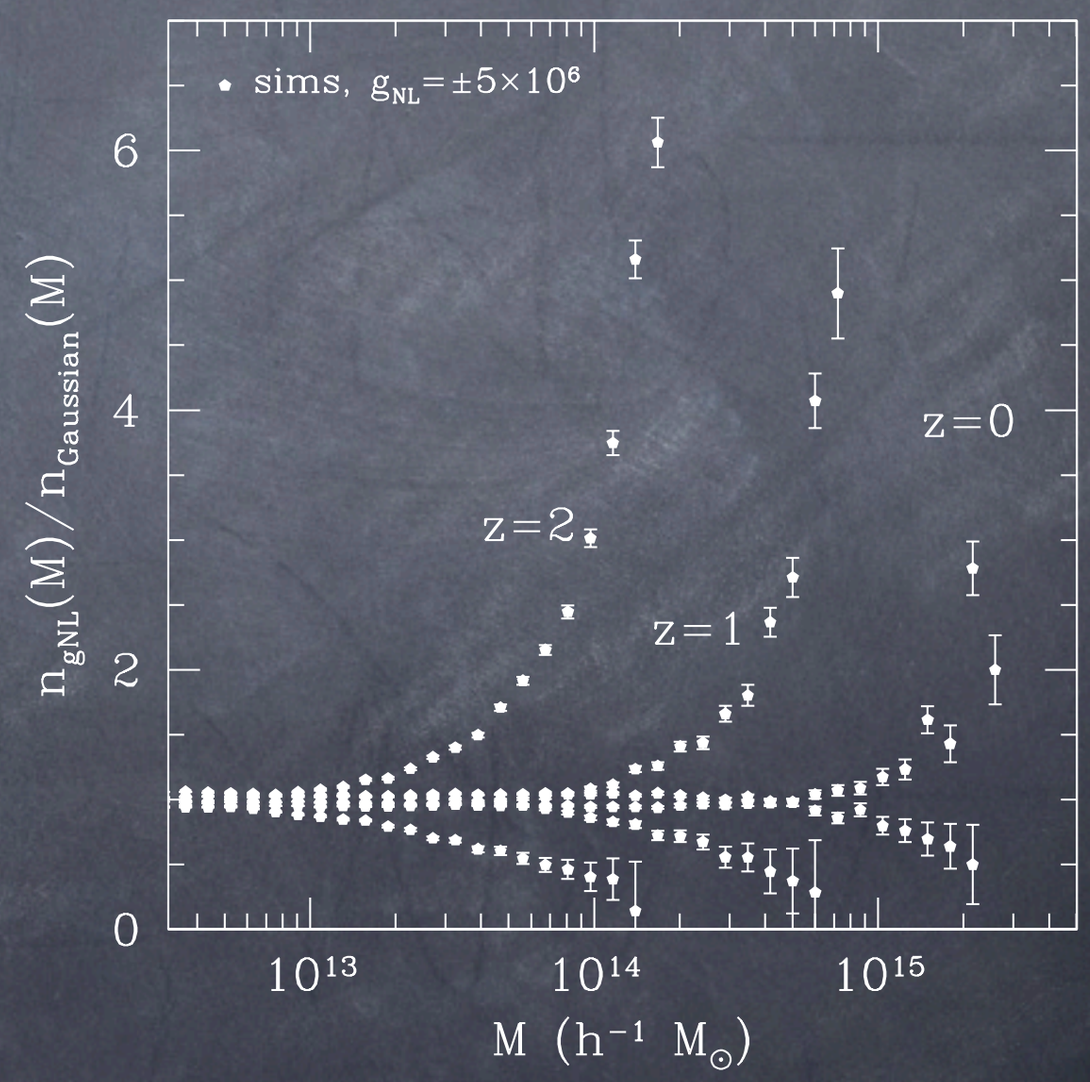
Non-Gaussianity affects the abundance of dark matter halos



($g_{NL} > 0$)

more extremely overdense regions --> more halos later

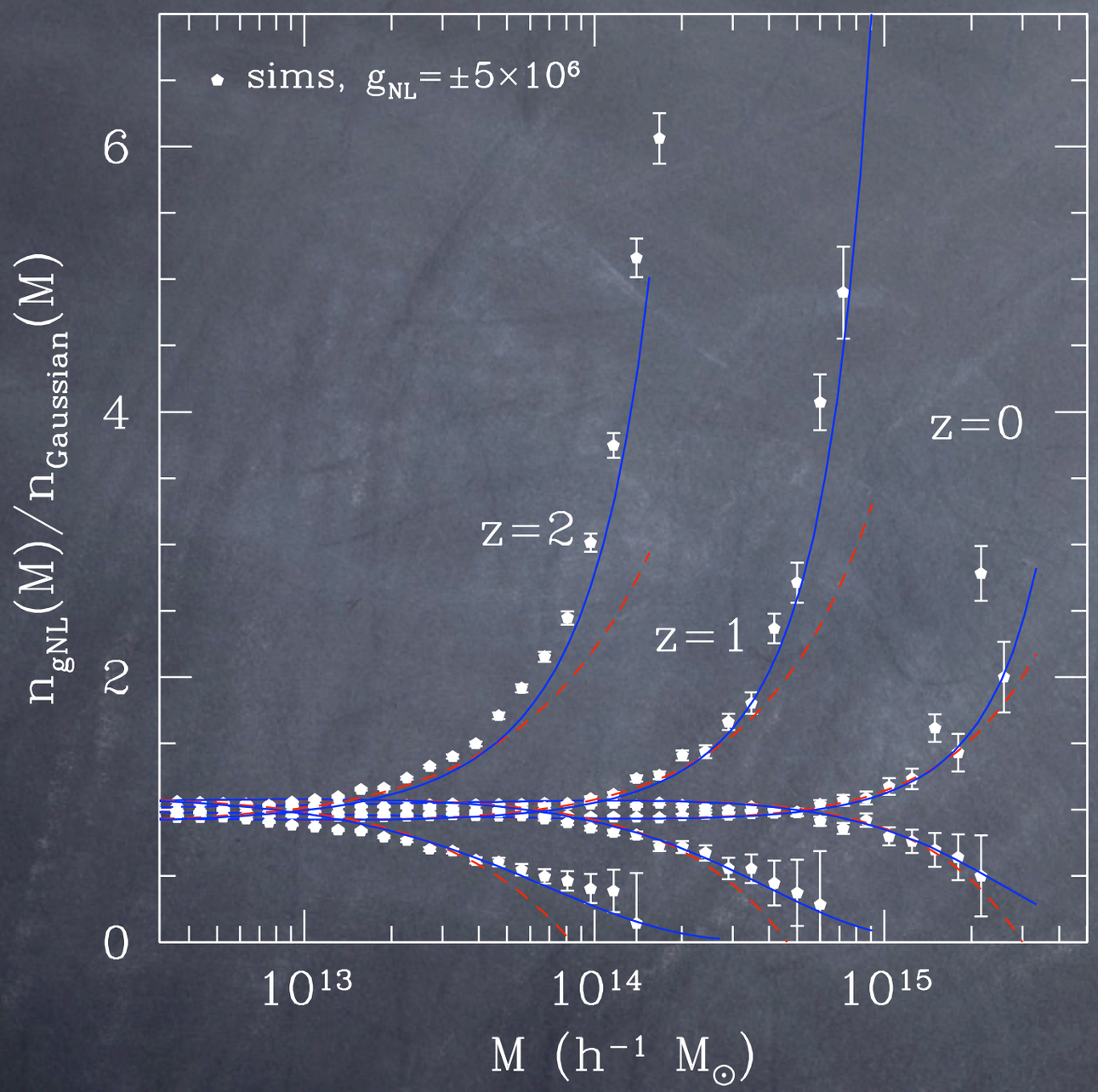
indeed!



N-body sims with non-Gaussian initial conditions

(see also Desjacques and Seljak 2010)

Simple analytic description? g_{NL} case



----- "Edgeworth mass function"

—— "log-Edgeworth mass function"

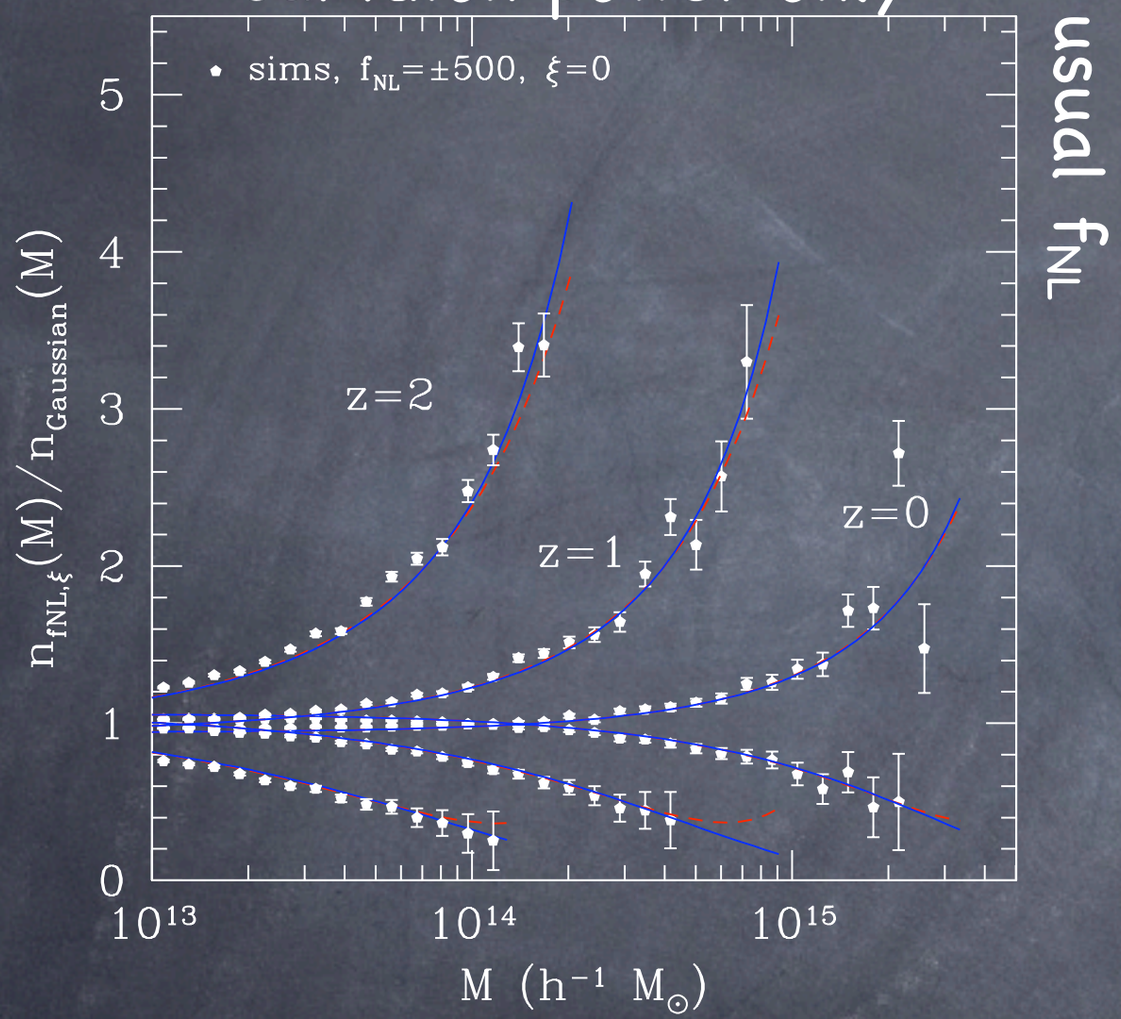
analytic works well!

uses only variance and kurtosis to describe non-Gaussian correction to mass function

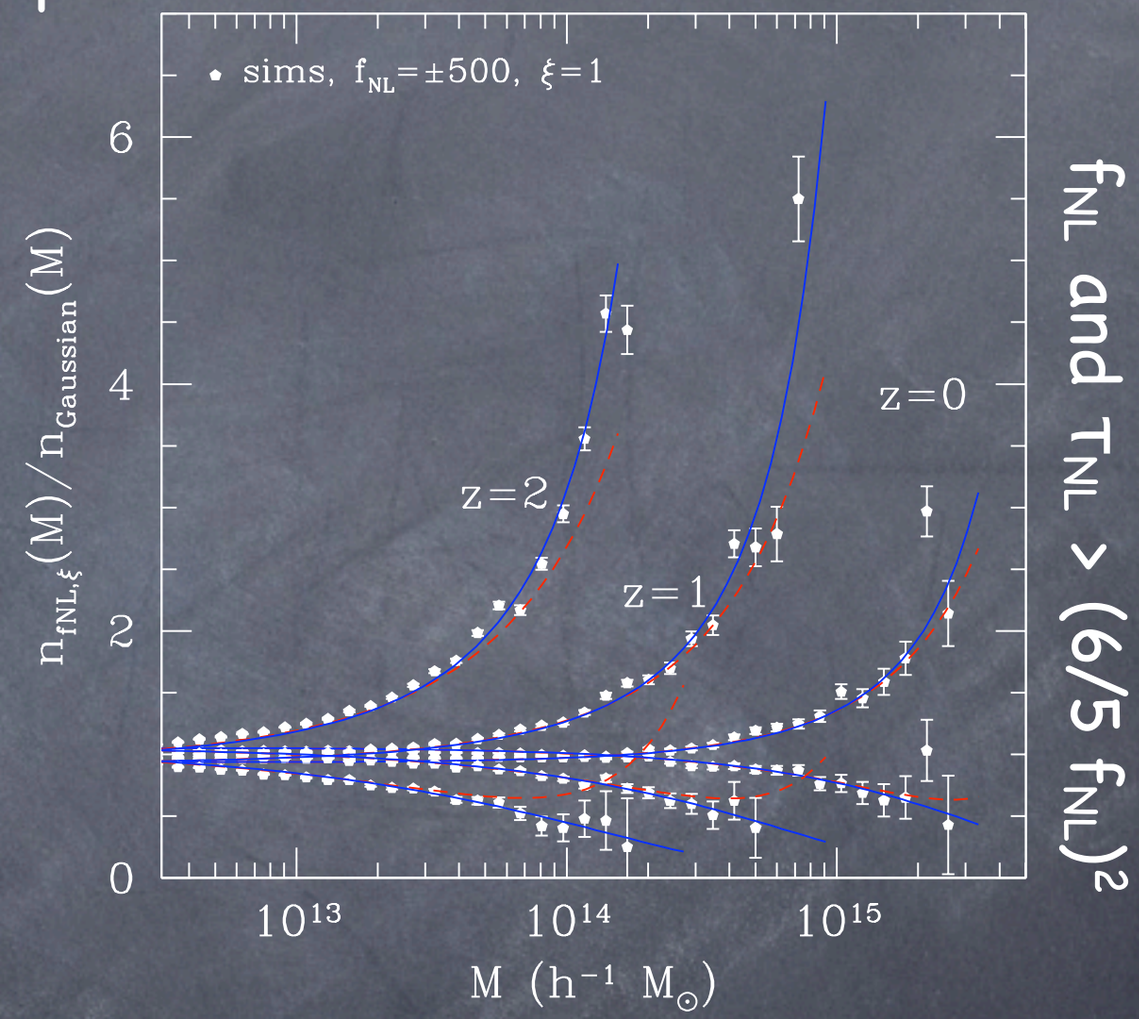
(see also Desjacques and Seljak 2010)

Simple analytic description? τ_{NL} case

curvaton power only



power from curvaton and inflaton



(recall, these models have same skewness, different kurtosis)

----- "Edgeworth mass function"

—— "log-Edgeworth mass function"

analytic prescription just uses variance, skewness, kurtosis

Non-zero g_{NL} and τ_{NL} can significantly change the abundance of massive clusters

We found an analytic formula using only the skewness and kurtosis of the 1-point PDF that seems to work well

--> perhaps it works for more general NG initial conditions

Next:

Can one detect g_{NL} and τ_{NL} with rare objects?

Can one distinguish between f_{NL}, g_{NL} and τ_{NL} with rare objects?

How about more general non-Gaussian initial conditions?