

The Mass Function

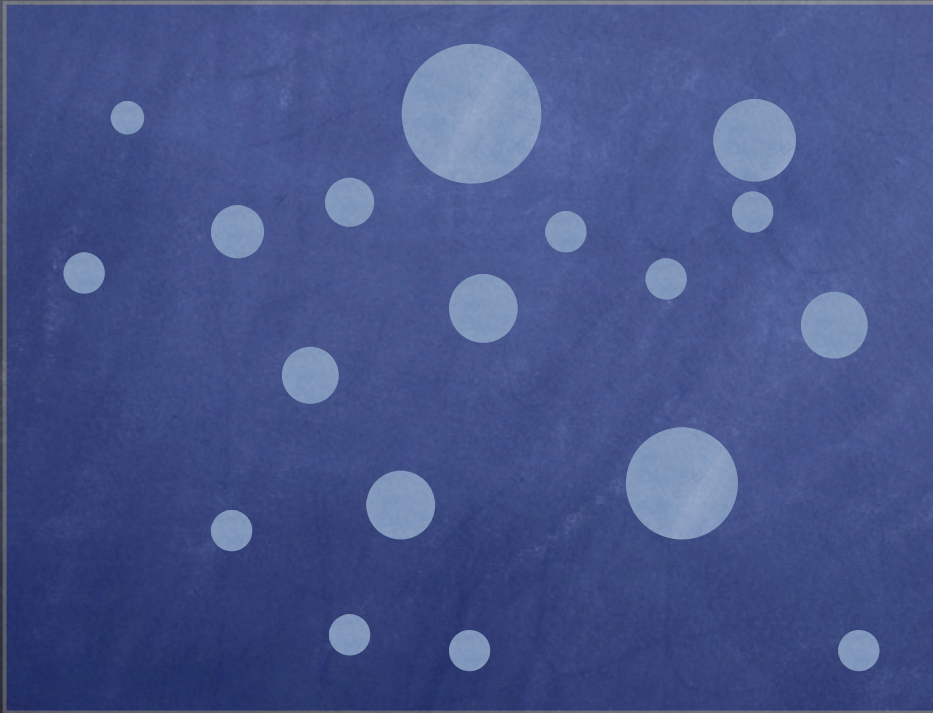
Marilena LoVerde
University of Chicago

The Mass Function

- What is it?
- Non-Gaussianity in the mass function
- Are we done?

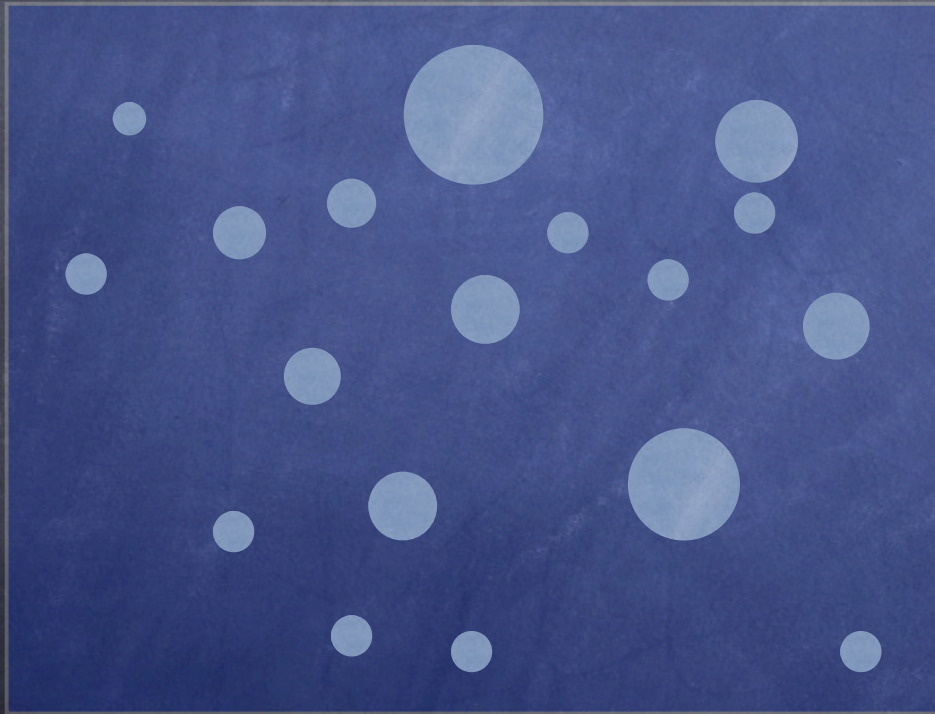
What is the mass function?

$\frac{dn}{dM} dM =$ average number density of
dark matter halos with
mass between $M, M+dM$



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probe of ρ_m , σ_8 , dark energy, primordial non-Gaussianity. . .

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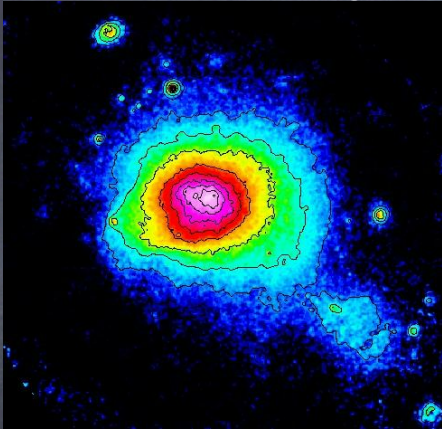


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How do we see the halos?

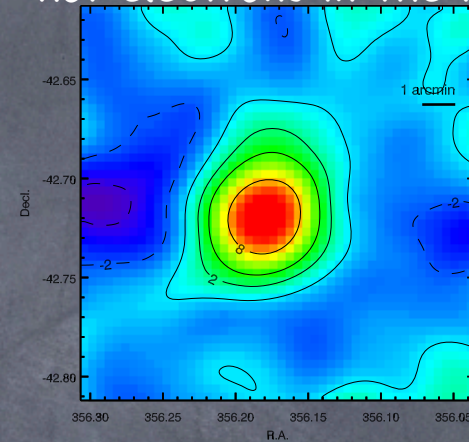
X-ray luminosity of gas in halo



richness
(number of galaxies in the halo)



Sunyaev-Zel'dovich effect
(CMB photons scattering off
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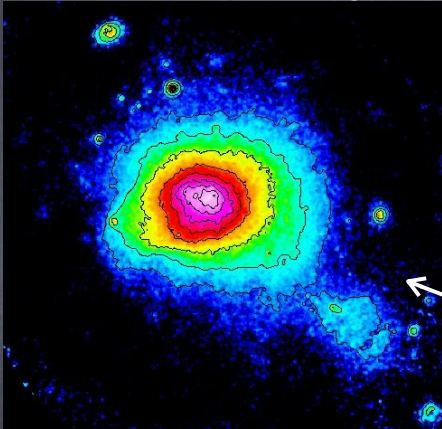


gravitational lensing of galaxies
behind halo

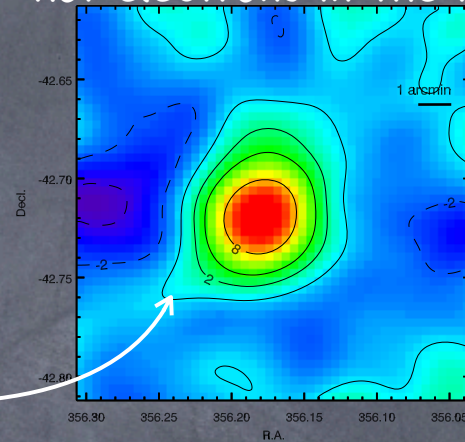


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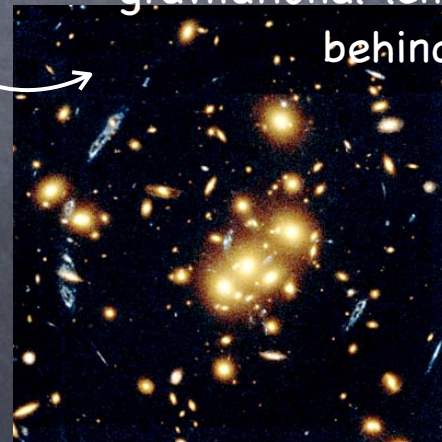


halo mass

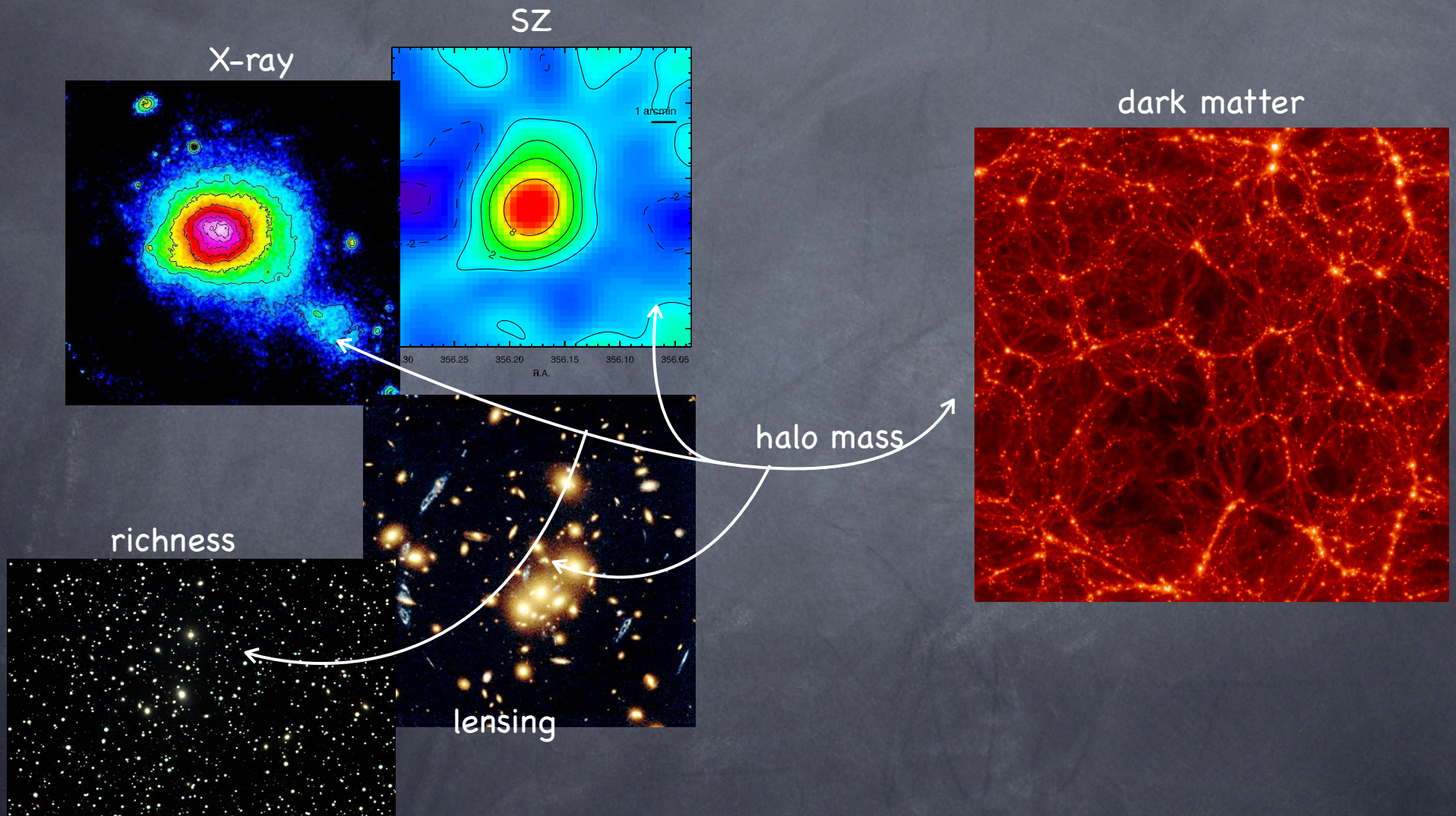
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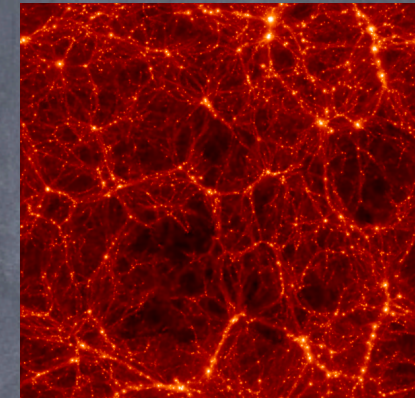
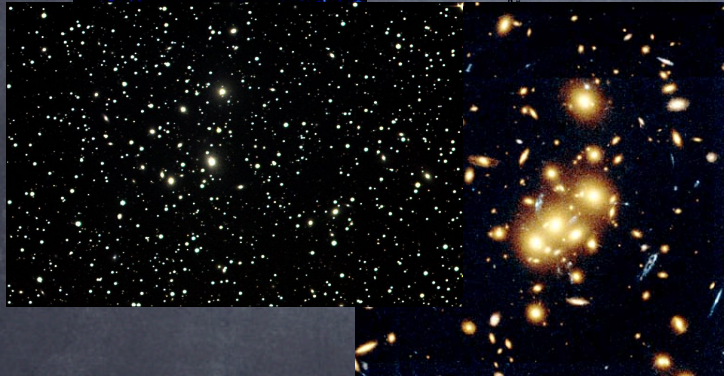
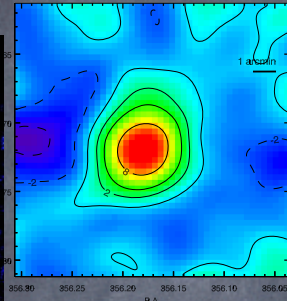
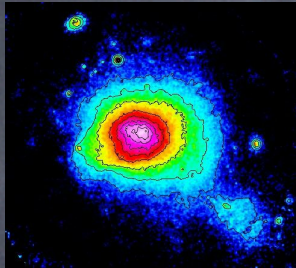


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What is the mass function?

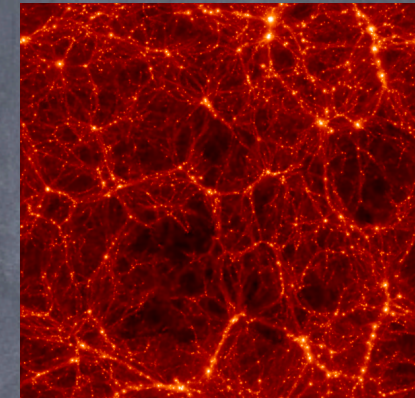
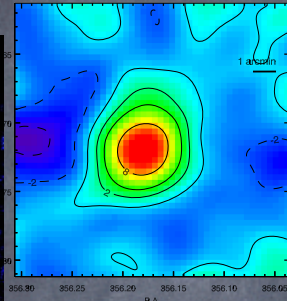
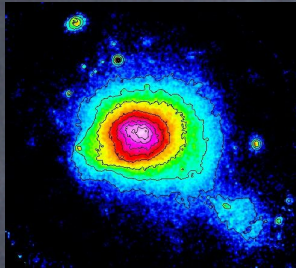
halo mass \leftrightarrow currency
between different
observables



mass function \leftrightarrow
currency between
observables and theory

What is the mass function?

halo mass \leftrightarrow currency
between different
observables



what's a halo?

function \leftrightarrow

currency between

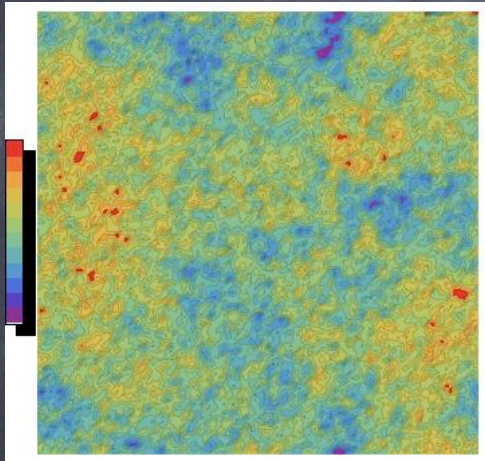
observables and theory

How does primordial non-Gaussianity
impact the mass function?

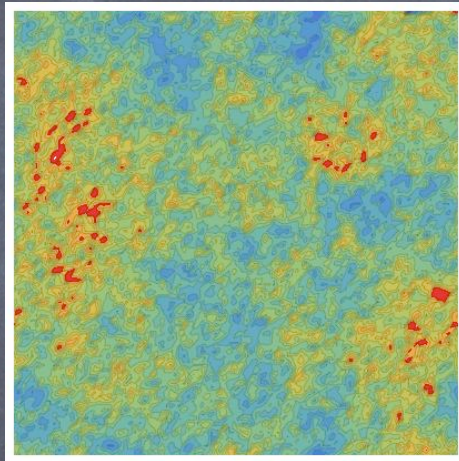
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Example non-Gaussian initial conditions

Gaussian

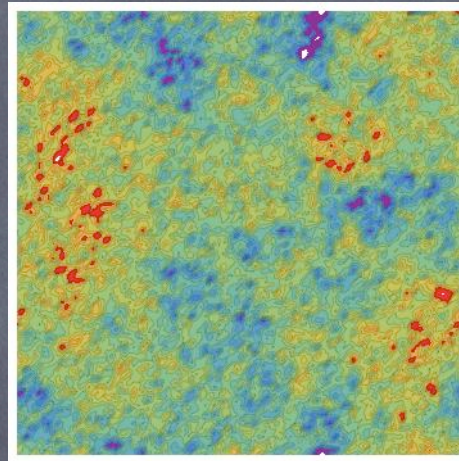


positive skewness



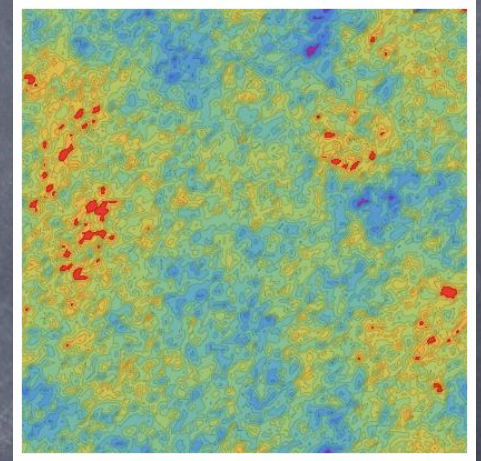
$$(f_{\text{NL}}, \tau_{\text{NL}} = f_{\text{NL}}^2)$$

no skewness, positive kurtosis



$$(g_{\text{NL}})$$

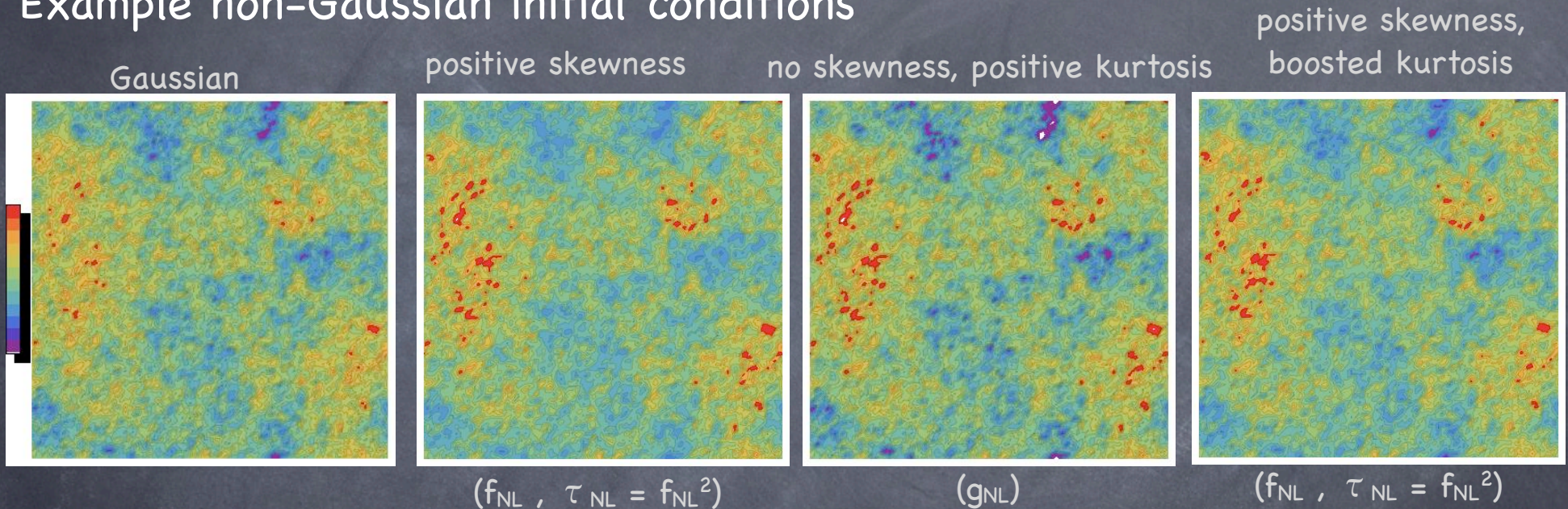
positive skewness,
boosted kurtosis



$$(f_{\text{NL}}, \tau_{\text{NL}} = f_{\text{NL}}^2)$$

How does primordial non-Gaussianity impact the mass function?

Example non-Gaussian initial conditions



non-Gaussianity changes the abundance of **rare fluctuations** in the initial density field

How does primordial non-Gaussianity impact the mass function?

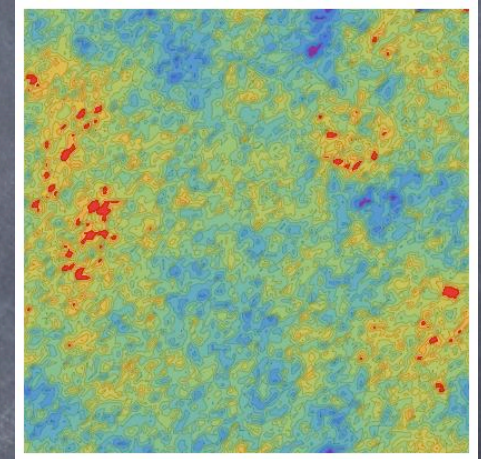
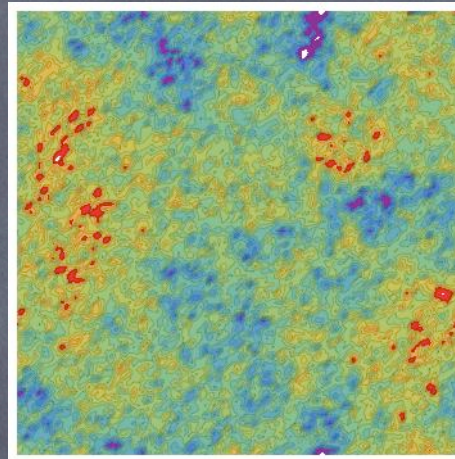
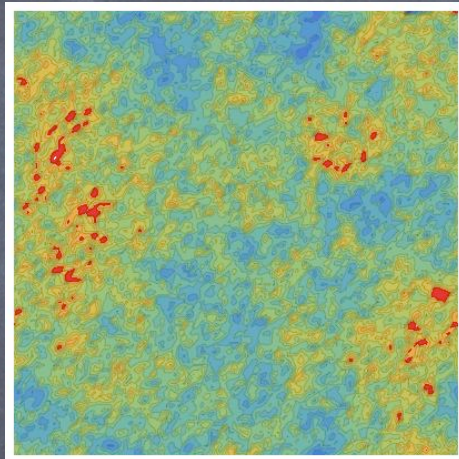
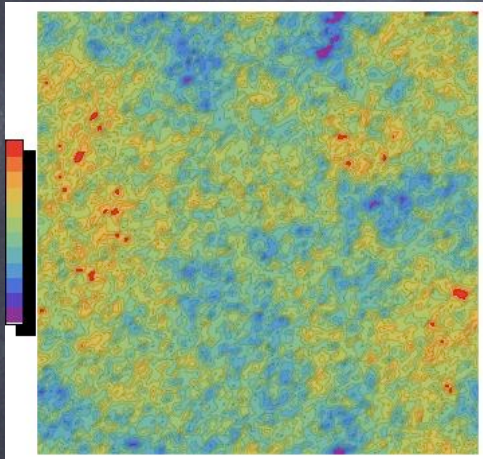
Example non-Gaussian initial conditions

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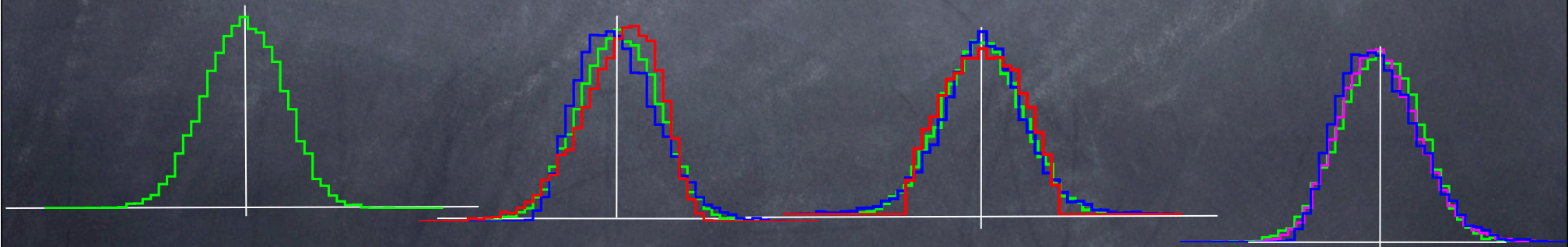
positive skewness,
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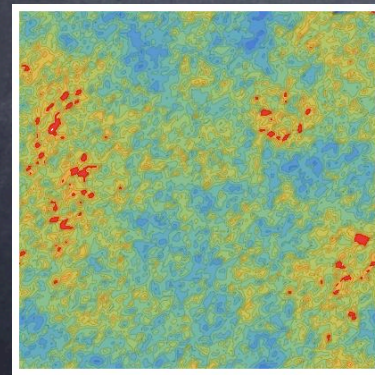
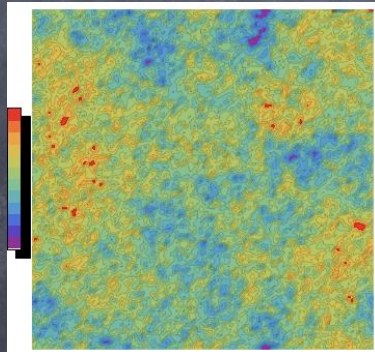
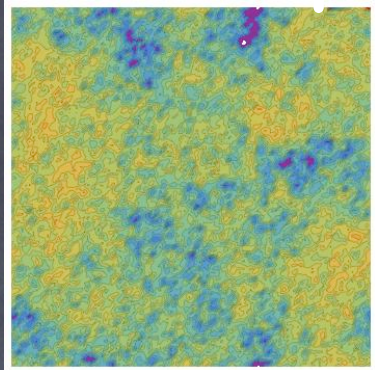
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$$(g_{\text{NL}})$$

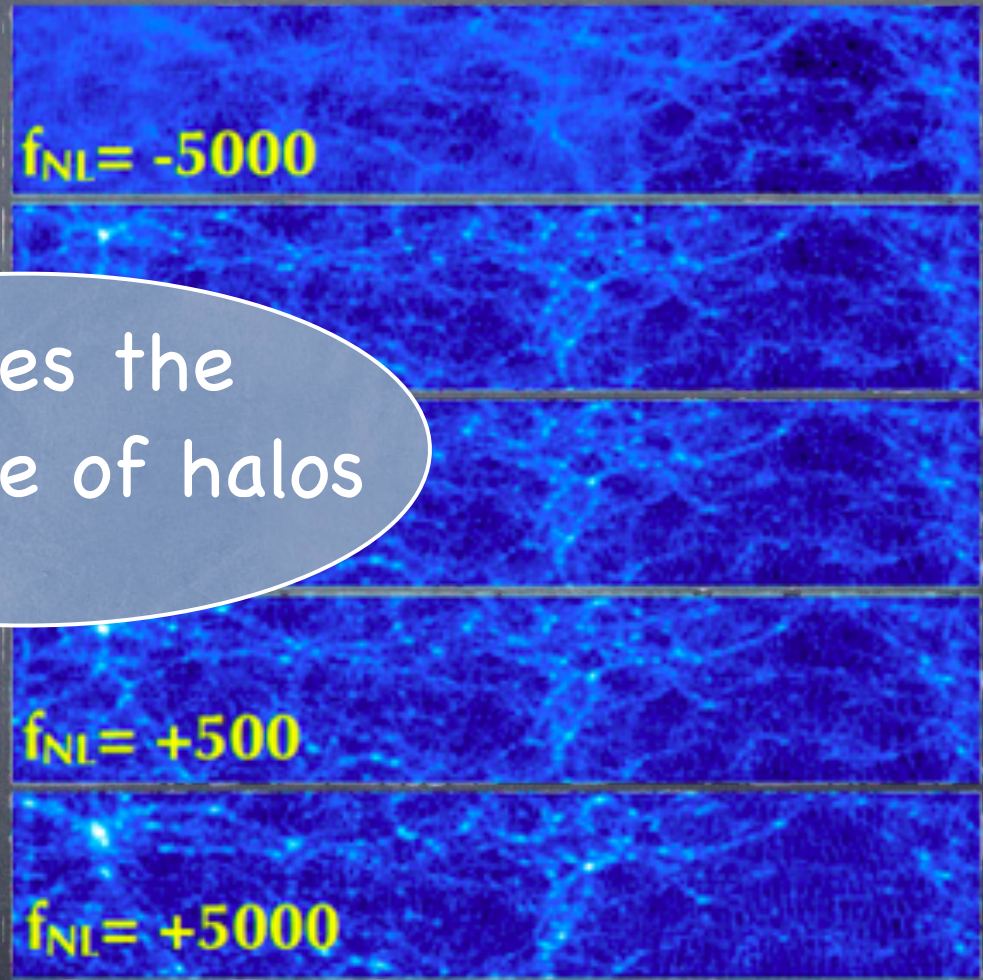
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How does primordial non-Gaussianity impact the mass function?

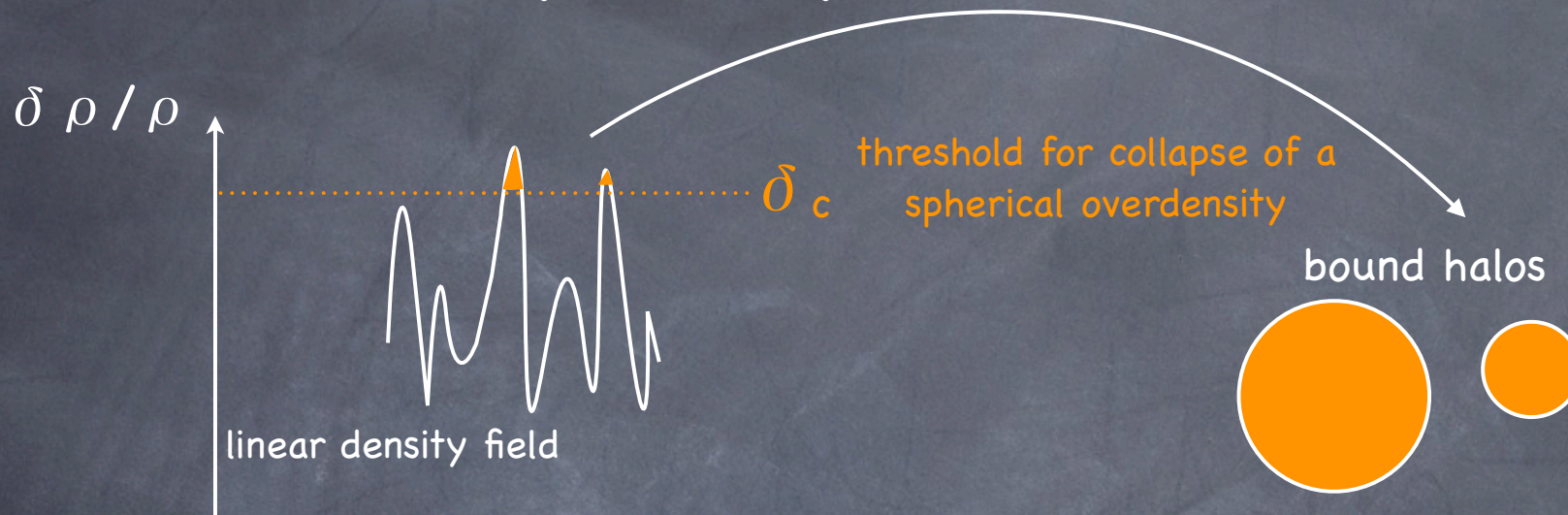


changes the abundance of halos



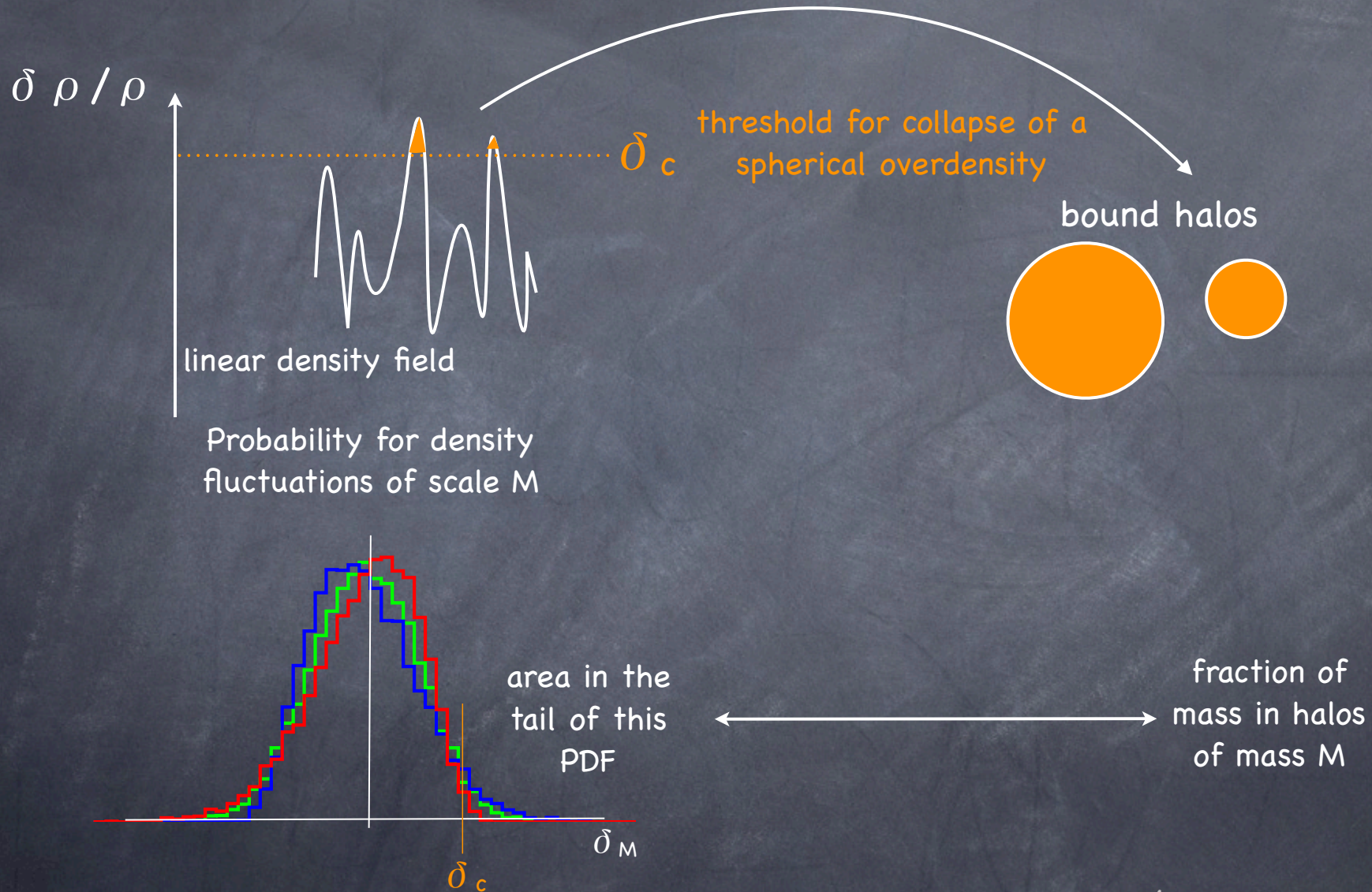
375 Mpc/h

Simplest possible model



(Press & Schechter 1974)

Simplest possible model

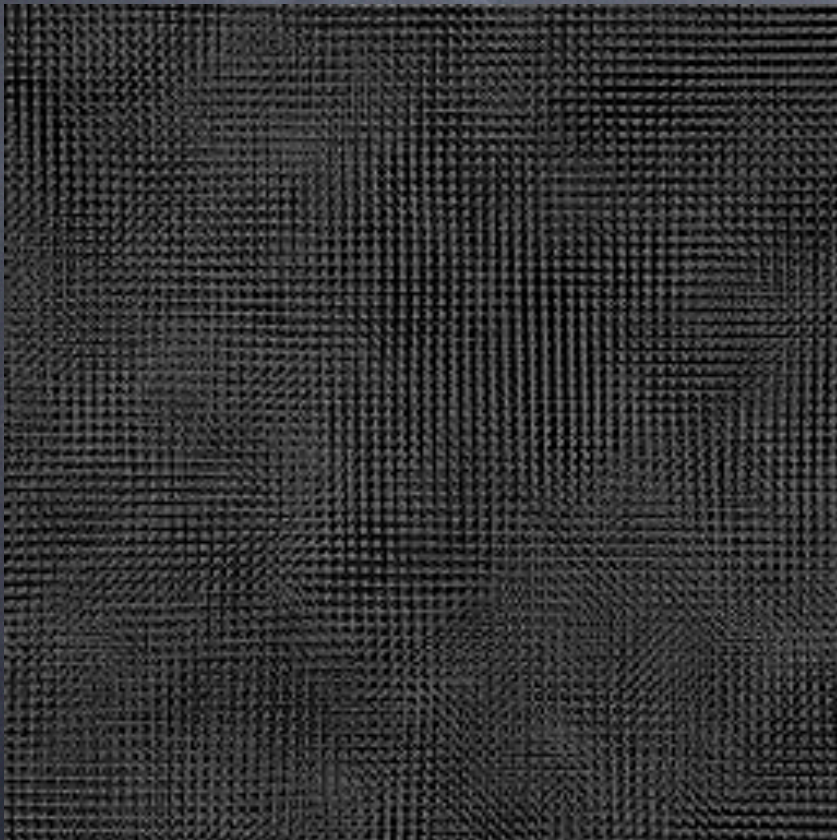


(Press & Schechter 1974)

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

Simplest possible model

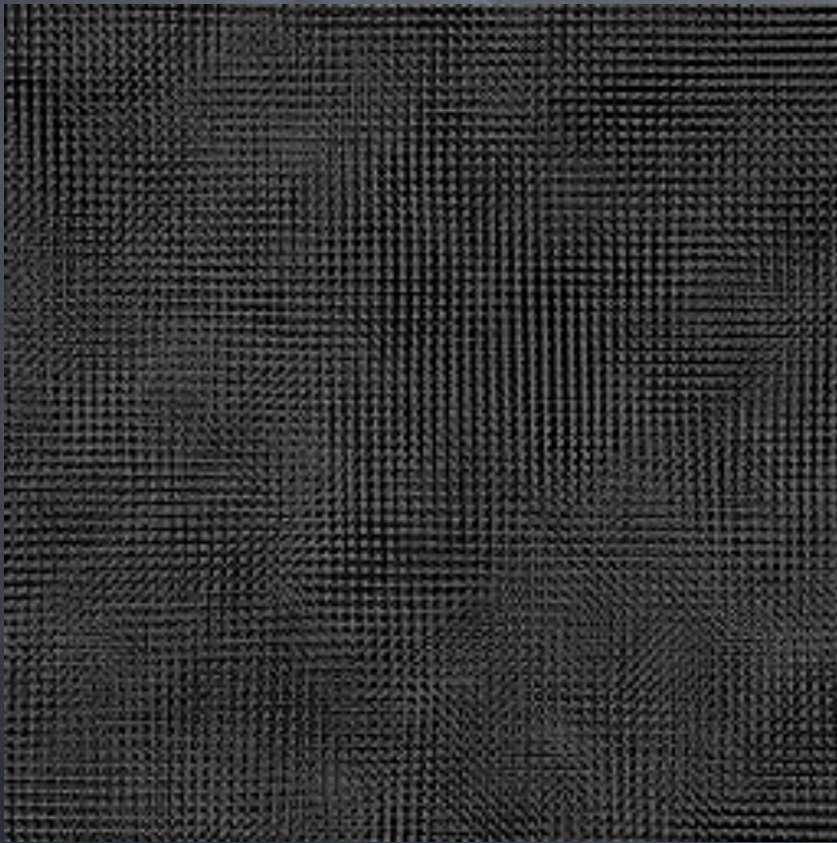
Is there a good reason this
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stolen from LANL astro group http://qso.lanl.gov/pictures/cdm_k1.mpg

Simplest possible model

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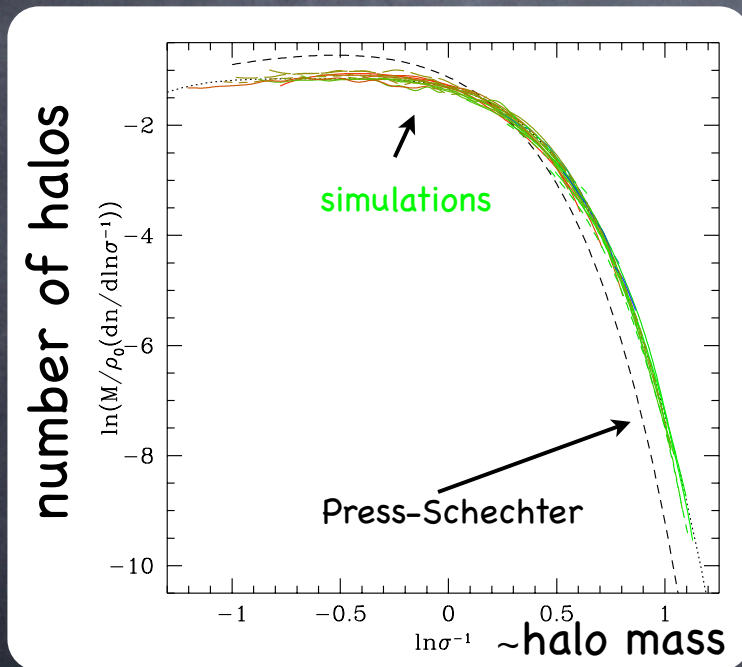
NO!

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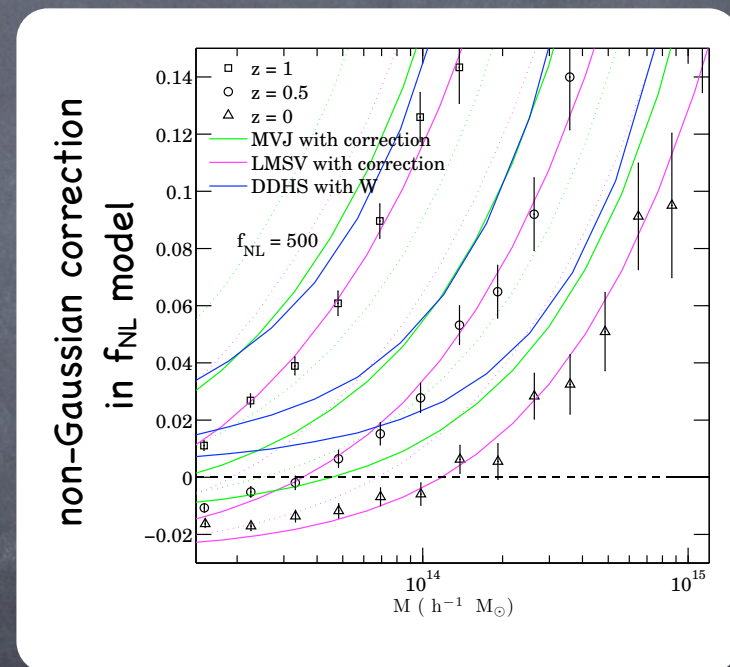
Does it work?

Gaussian:



Jenkins et al 2000

f_{NL} non-Gaussian:



Pillepich, Porciani, Hahn 2008

ridiculously well given assumptions!

well enough for precision cosmology?

Calibration of sims remains the standard

Large scale bias and the peak background split

Ravi K. Sheth¹ & Giuseppe Tormen²

¹ *Max-Planck-Institut für Astrophysik, 85740 Garching, Germany*

PRECISION DETERMINATION OF THE MASS FUNCTION OF DARK MATTER HALOS

MICHAEL S. WARREN¹, KEVORK ABZAJIAN¹, DANIEL E. HOLZ¹ AND LUIS TEODORO^{1,2}

Draft version February 2, 2008

THE HALO MASS FUNCTION: HIGH-REDSHIFT EVOLUTION AND UNIVERSALITY

ZARIJA LUKIĆ¹, KATRIN HEITMANN², SALMAN HABIB³, SERGEI BASHINSKY³, AND PAUL M. RICKER^{1,4}

¹ Dept. of Astronomy, University of Illinois, Urbana, IL 61801

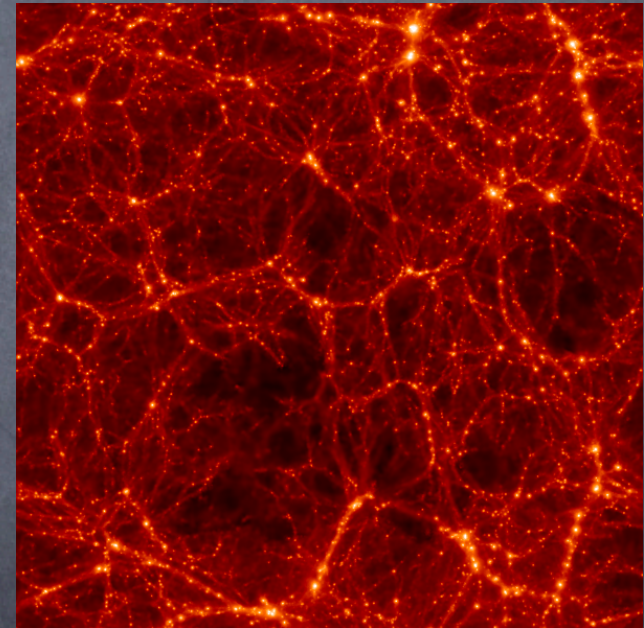
² ISR-1, ISR Division, Los Alamos National Laboratory, Los Alamos, NM 87545

³ T-9, Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545

TOWARD A HALO MASS FUNCTION FOR PRECISION COSMOLOGY: THE LIMITS OF UNIVERSALITY

JEREMY TINKER^{1,2}, ANDREY V. KRAVTSOV^{1,2,3}, ANATOLY KLYPIN⁴, KEVORK ABZAJIAN⁵,
MICHAEL WARREN⁶, GUSTAVO YEPES⁷, STEFAN GOTTLÖBER⁸, DANIEL E. HOLZ⁶

Draft version March 18, 2008



Nevertheless, this simple approach works pretty well for
the ratio $(dn_{NG}/dM)/(dn_G/dM)$

Plus it's useful to have something analytic

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How to get the PDF for $\delta(M)$?

- Measure PDF from realization of NG initial conditions (e.g. Sefusatti, Vale, Kadota, Frieman 2006; Dalal, Dore, Huterer, Shirokov 2007)
- Approximate PDF by some truncating a cumulant expansion (e.g. **asymptotic expansion** of Matarrese, Verde, Jimenez or **Edgeworth series** ML, Miller, Shandera, Verde 2007)
- Approximate PDF by truncating $\ln(\text{Edgeworth series})$

(ML & Smith 2011)

cumulants easy to compute, pretty insensitive to "shape" of polyspectra

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Plus it's useful to have something analytic

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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; Paranjape, Gordon, Hotchkiss 2011; Musso & Paranjape 2011; . . .

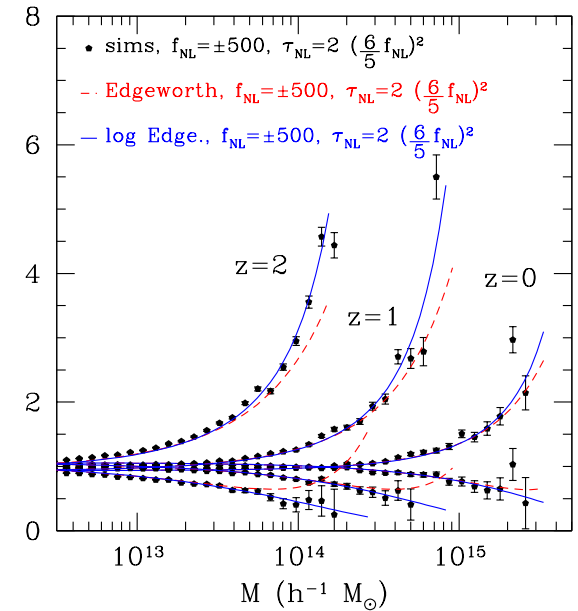
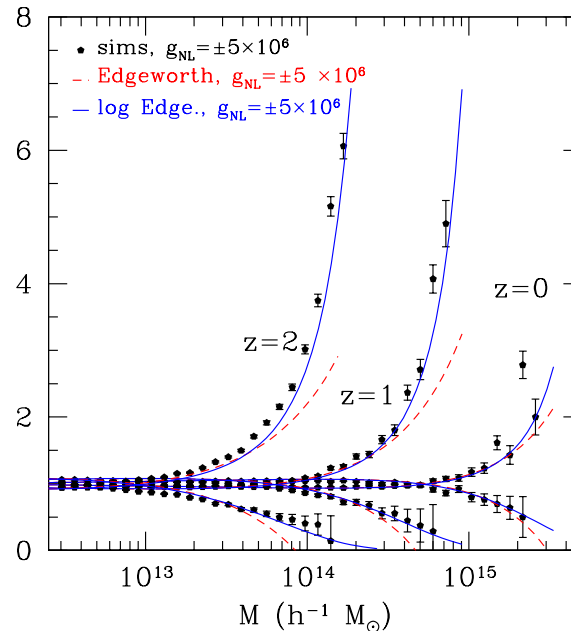
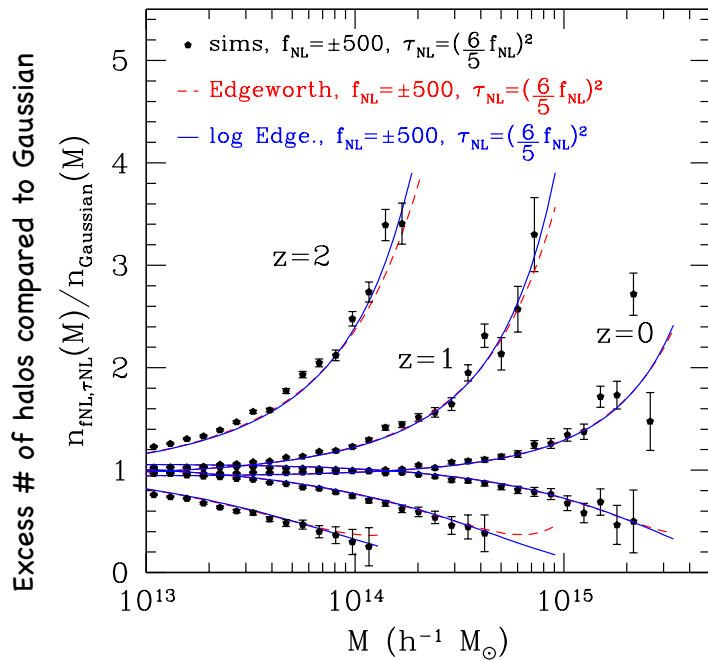
Compare with simulations

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

$$f_{NL}, \tau_{NL} = f_{NL}^2$$

$$g_{NL}$$

$$f_{NL}, \tau_{NL} = 2f_{NL}^2$$



kurtosis can have important effects
on the mass function!

see also Dalal, Dore, Huterer, Shirokov 2007; Grossi et al 2009; Kang, Norberg, Silk 2009; Pillepich, Porciani, Hahn 2009; Desjacques and Seljak 2010; Wagner, Verde, Boubekeur 2010

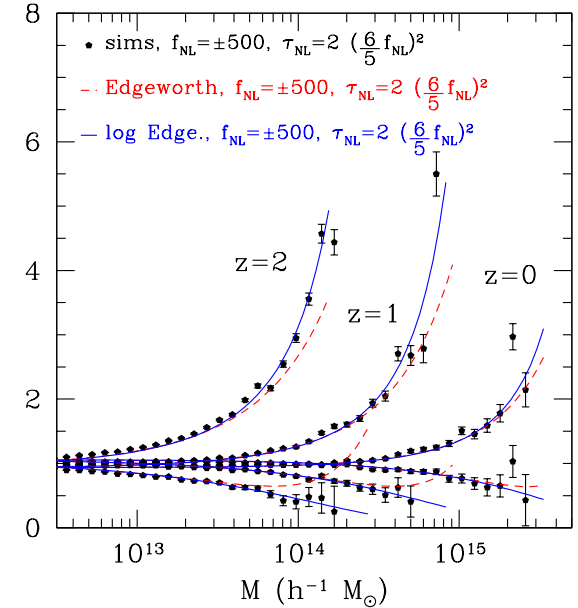
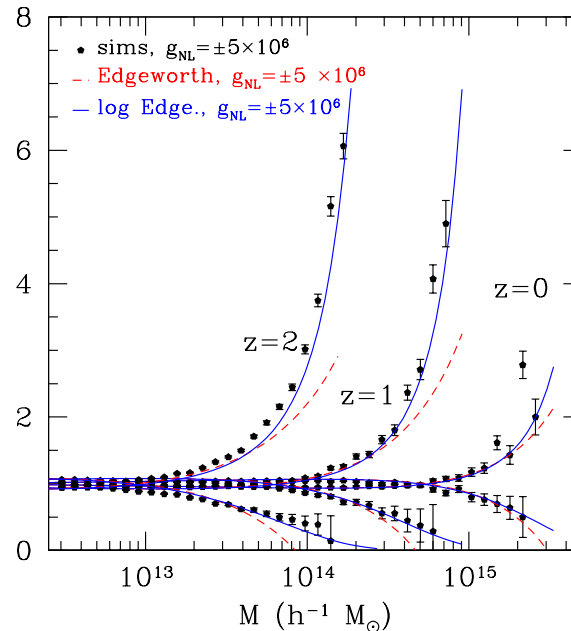
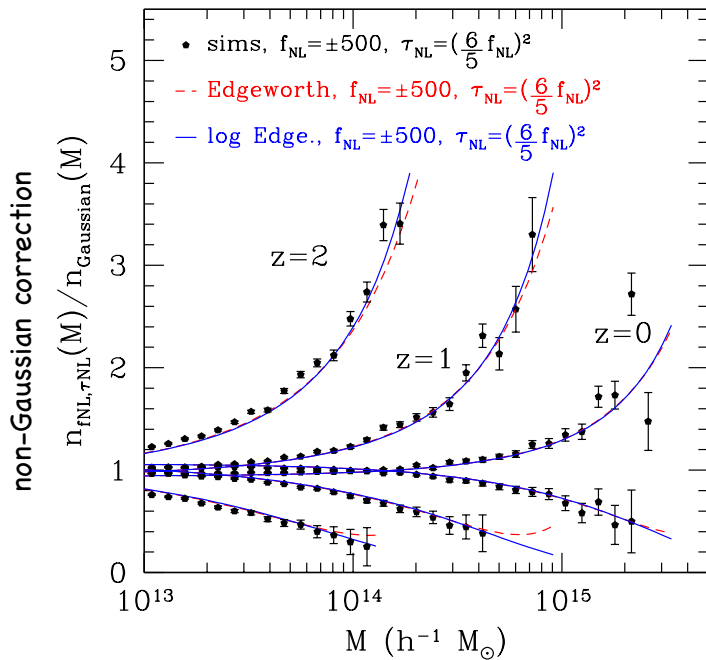
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$$g_{NL}$$

$$f_{NL}, \tau_{NL} = 2f_{NL}^2$$



the "log-Edgeworth" mass reliably captures NG effects for f_{NL} , g_{NL} , and τ_{NL} types of non-Gaussianity

Are we done? Can we do better?

- Same analytic expression in terms of cumulants works well for f_{NL} , g_{NL} , τ_{NL} (which are different shapes)

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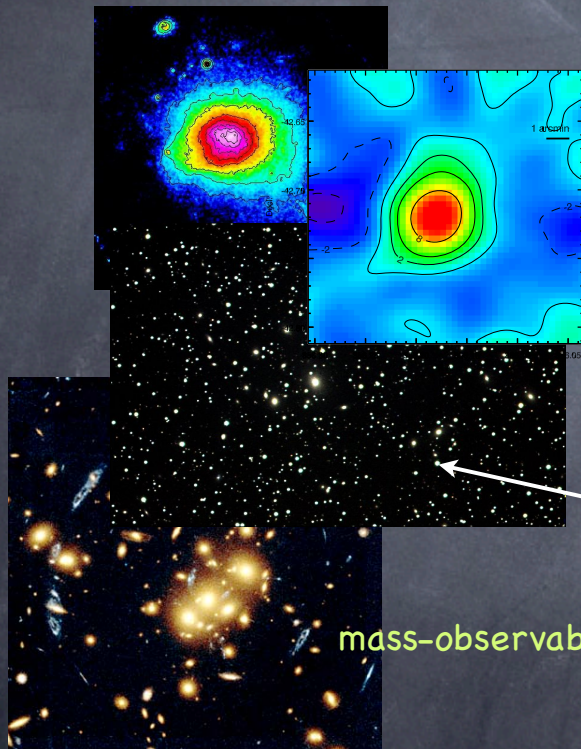
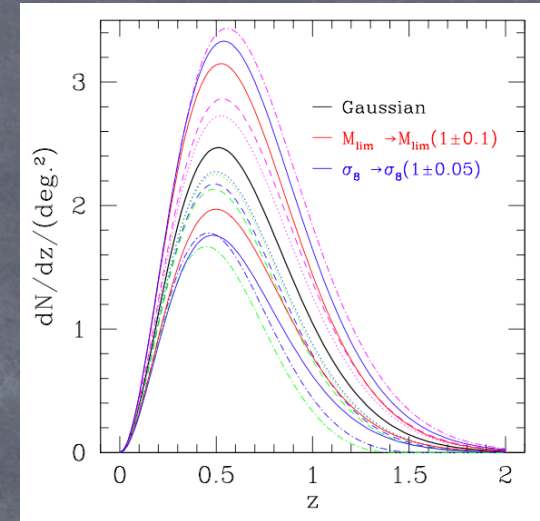
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- Marcello is hard at work finding ultimate analytic formula!

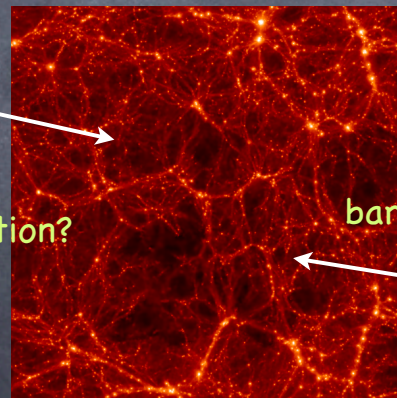
What remains?

Precision cluster cosmology is hard

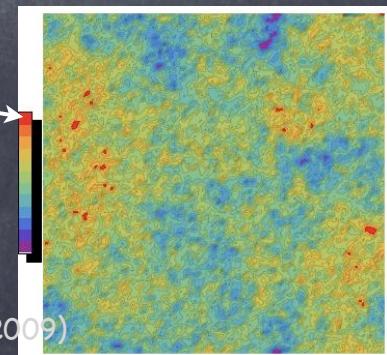
other degeneracies



mass-observable relation?



baryonic effects?



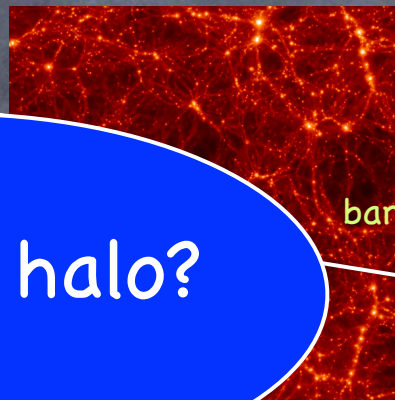
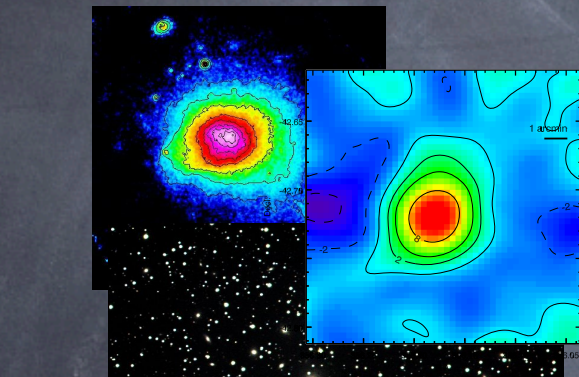
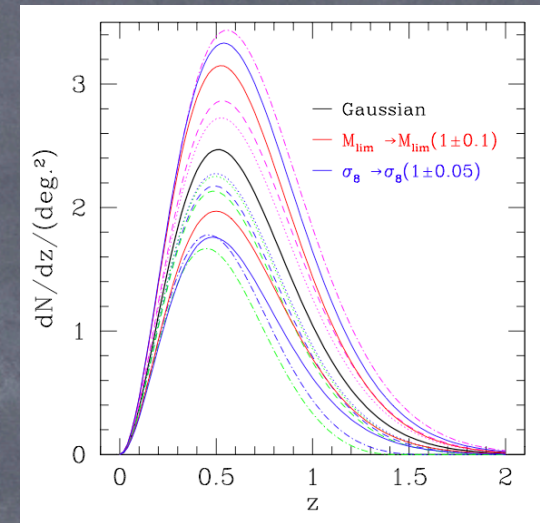
(e.g. Mantz, Allen, Rapetti, Ebeling 2010;
Rozo, Bartlett, Evrard, Rykoff 2012;
Mahdavi et al 2007, 2012; Marrone et al
2012. . .)

(e.g. Stanek, Rudd, Evrard 2009)

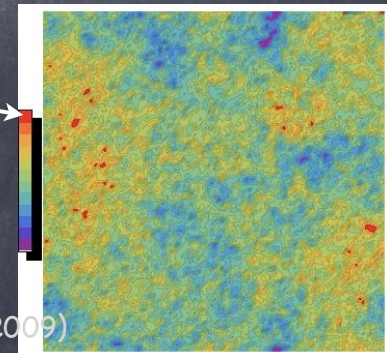
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what's a halo?



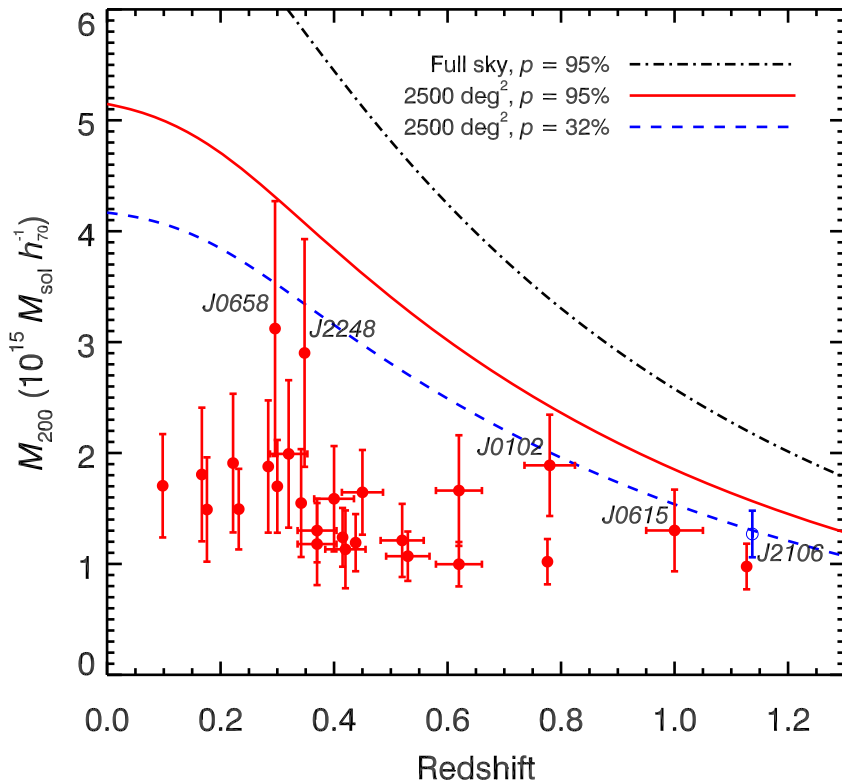
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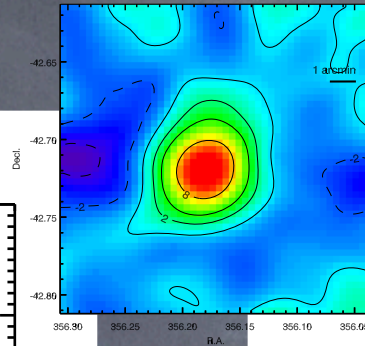
Current large-scale structure data:

$$f_{NL} = 20 \pm 450$$

most massive SPT clusters

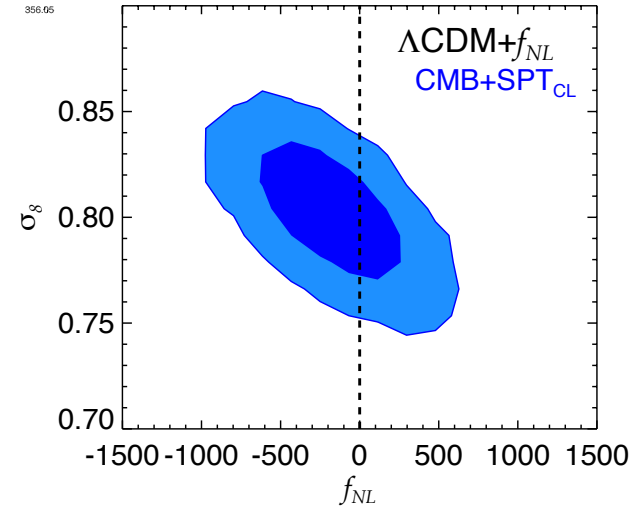


(Williamson et al 2011)



$$f_{NL} = -192 \pm 310$$

SPT clusters



(Benson et al 2011)

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- “Extended Press-Schechter” approaches work for non-local forms too (Wagner, Verde, Boubekur)
- Marcello (and others!) is (are!) hard at work finding ultimate analytic formula!
- Lots of challenges for non-Gaussianity with clusters -- but the data exists/will arrive! (and these challenges aren't different from constraining dark energy with clusters)

