# Constraining primordial non-Gaussianity with the eROSITA cluster survey

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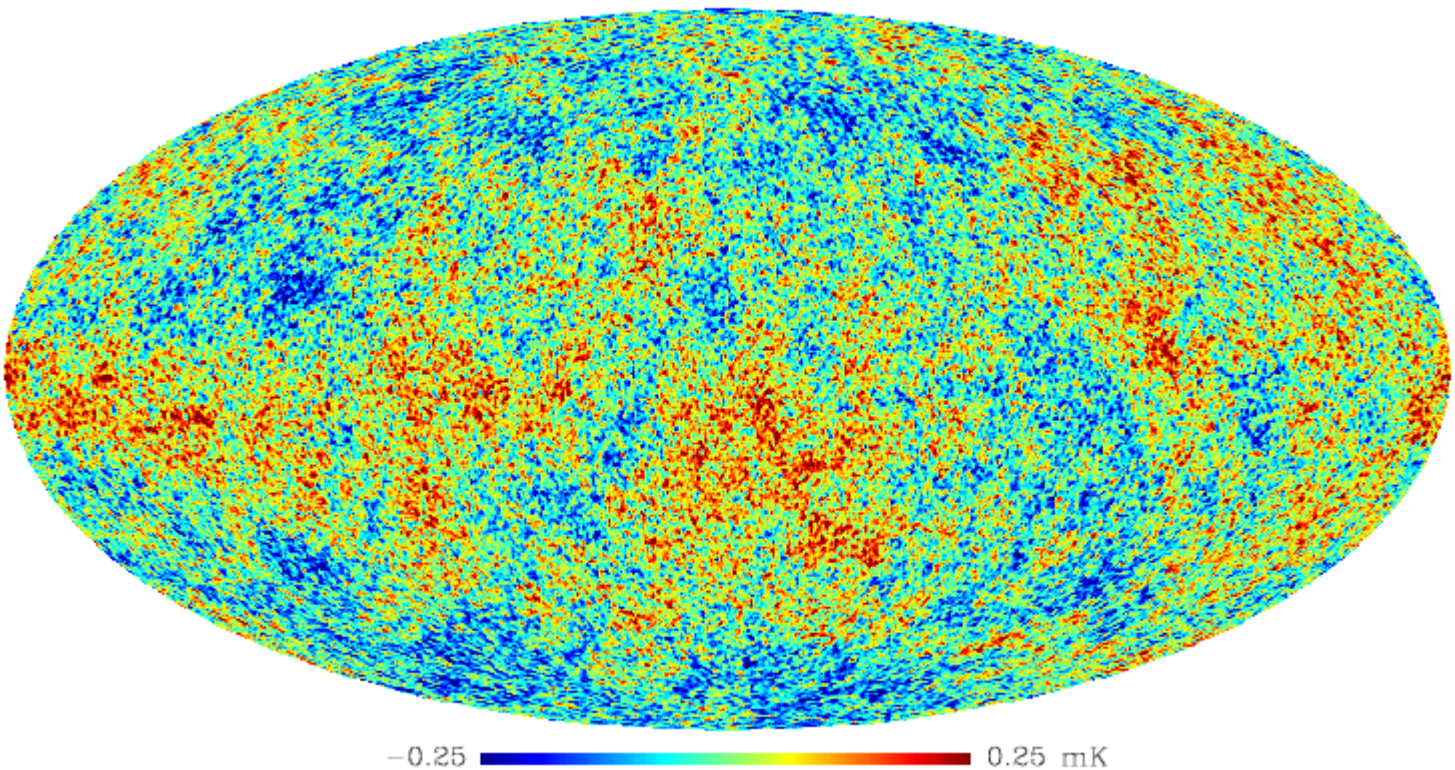
with C. Porciani (Bonn), T. Reiprich (Bonn), O.Hahn (KIPAC), S.Matarrese (Padova)

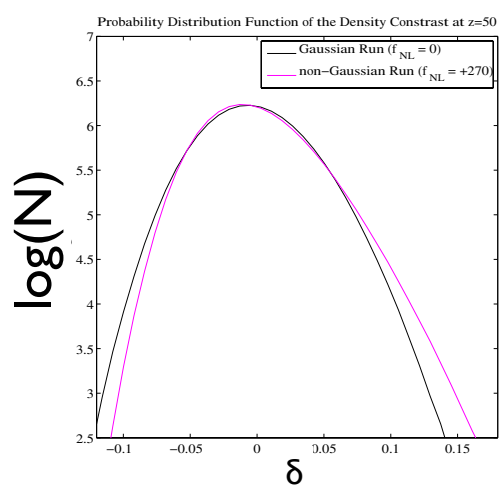
# The initial conditions of the Universe

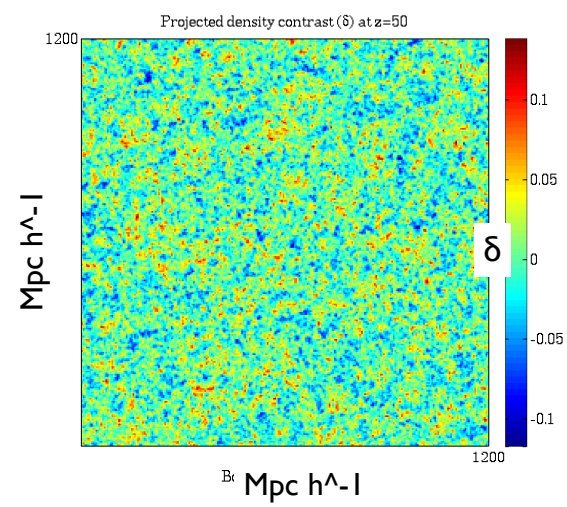



The initial seeds have been so far modeled as a Gaussian random field out of mathematical convenience....

# Outline:

1. What is primordial non-Gaussianity?
2. Non-Gaussianity from gravitational instability
3. Effects of primordial non-Gaussianity on the large-scale structure
4. Current and future constraints
5. Cosmology and more with the eROSITA X-ray telescope



# Gaussian vs non-Gaussian Random Variable

$$\mu_n = \langle (X - \langle X \rangle)^n \rangle = \int_{-\infty}^{+\infty} P_X(x)\ (x - \langle X \rangle)^n\ dx$$

For a GAUSSIAN RANDOM VARIABLE the second moment contains ALL the information

→ Variance $\sigma^2$ (measure of spread)

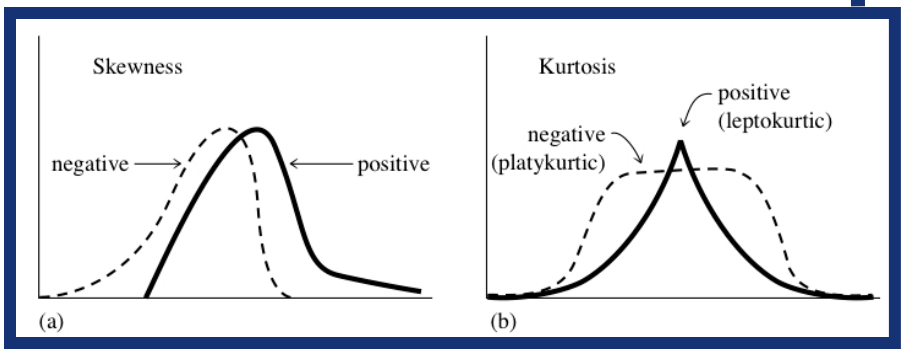
For a RANDOM VARIABLE with a NON-GAUSSIAN DISTRIBUTION higher-order moments are a priori not vanishing

→ Variance $\sigma^2$ (measure of spread)

→ Skewness $\gamma_1 = \mu_3/\sigma^3$ (measure of lopsidedness)

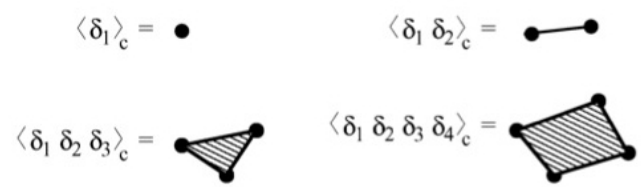
→ Kurtosis $\gamma_2 = \mu_4/\sigma^4 - 3$ (measure of "peakedness")

→ .....



# Gaussian vs non-Gaussian Fields

Let $g(\mathbf{x}) = \delta_m, \Phi, \delta T_{CMB}, \ldots$




For a GAUSSIAN RANDOM FIELD
the 2-point correlation function contains ALL the information

→ 2-point Correlation Function $\xi_2(r)$

$$
\begin{aligned}
\xi_2(\mathbf{x}_1, \mathbf{x}_2) &= \langle g(\mathbf{x}_1) \; g(\mathbf{x}_2) \rangle \\
\xi_3(\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3) &= \langle g(\mathbf{x}_1) g(\mathbf{x}_2) g(\mathbf{x}_3) \rangle_c \\
&\vdots \\
\xi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) &= \langle g(\mathbf{x}_1) \ldots g(\mathbf{x}_n) \rangle_c
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For a NON-GAUSSIAN RANDOM FIELD
higher-order point functions are a priori not vanishing

→ 2-point Correlation Function $\xi_2(r)$

→ 3-point Correlation Function $\xi_3$

→ 4-point Correlation Function $\xi_4$

→ .....

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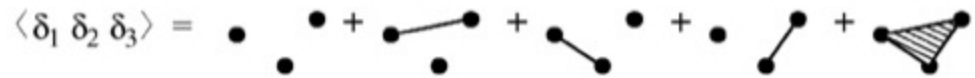


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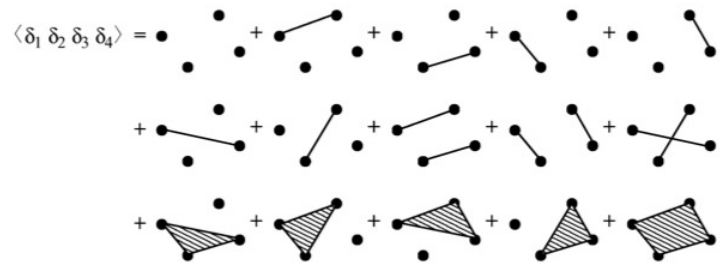


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# Gaussian vs non-Gaussian Fields

Let $g(\mathbf{x}) = \delta_m, \Phi, \delta T_{CMB}, \ldots$

$$\tilde{g}(\mathbf{k}) = \int d\mathbf{x}^3 g(\mathbf{x}) e^{-i\mathbf{k}\cdot\mathbf{x}}$$

For a GAUSSIAN RANDOM FIELD
the 2-point correlation function contains ALL the information

→ Powerspectrum P(k)

$$\begin{aligned}
\langle \tilde{g}(\mathbf{k}_1)\ \tilde{g}(\mathbf{k}_2) \rangle &= (2\pi)^3\ \delta_D(\mathbf{k}_1 + \mathbf{k}_2)\ P(k_1, k_2) \\
\langle \tilde{g}(\mathbf{k}_1)\ \tilde{g}(\mathbf{k}_2)\ \tilde{g}(\mathbf{k}_3) \rangle_c &= (2\pi)^3\ \delta_D(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3)\ B(k_1, k_2, k_3) \\
\langle \tilde{g}(\mathbf{k}_1)\ \tilde{g}(\mathbf{k}_2)\ \tilde{g}(\mathbf{k}_3)\ \tilde{g}(\mathbf{k}_4) \rangle_c &= (2\pi)^3\ \delta_D(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3 + \mathbf{k}_4)\ T(k_1, k_2, k_3, k_4) \\
&\vdots \\
\langle \tilde{g}(\mathbf{k}_1)\ \ldots\ \tilde{g}(\mathbf{k}_n) \rangle_c &= (2\pi)^3\ \delta_D(\mathbf{k}_1 + \cdots + \mathbf{k}_n)\ P_n(k_1, \ldots, k_n)
\end{aligned}$$

For a NON-GAUSSIAN RANDOM FIELD
higher-order point functions are a priori not vanishing

→ Powerspectrum P(k)

→ Bispectrum $B(k_1,k_2,k_3)$

→ Trispectrum $T(k_1,k_2,..)$

→ .....

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→ .....

Two NG fields may have the same P(k) and yet have completely different topologies!!!

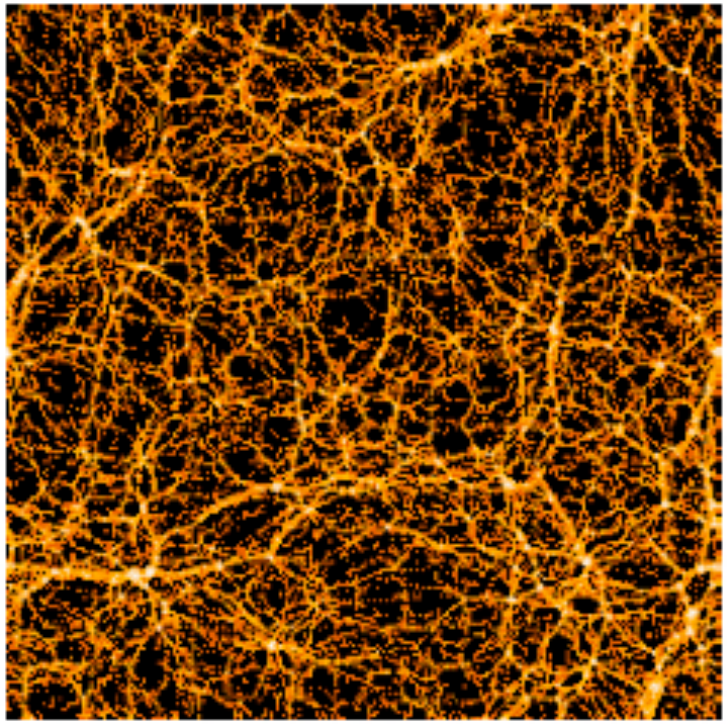
# Non-Gaussianity: phase information

Gaussian fields have angle phases which are independently distributed and uniformly random in the interval [0, 2pi].
For non-Gaussian fields those phases are coupled.

$$\delta(\mathbf{x}) = \frac{\rho(\mathbf{x}) - \rho_0}{\rho_0}$$

$$\delta(\mathbf{x}) = \sum \tilde{\delta}(\mathbf{k}) \exp(i\mathbf{k}\cdot\mathbf{x})$$

$$\tilde{\delta}(\mathbf{k}) = |\tilde{\delta}(\mathbf{k})| \exp(i\phi_{\mathbf{k}})$$



Coles & Chiang , Nature 2000

# Non-Gaussianity: phase information

What happens if we reshuffle randomly the phases between Fourier modes of this highly non-Gaussian gravitational field?

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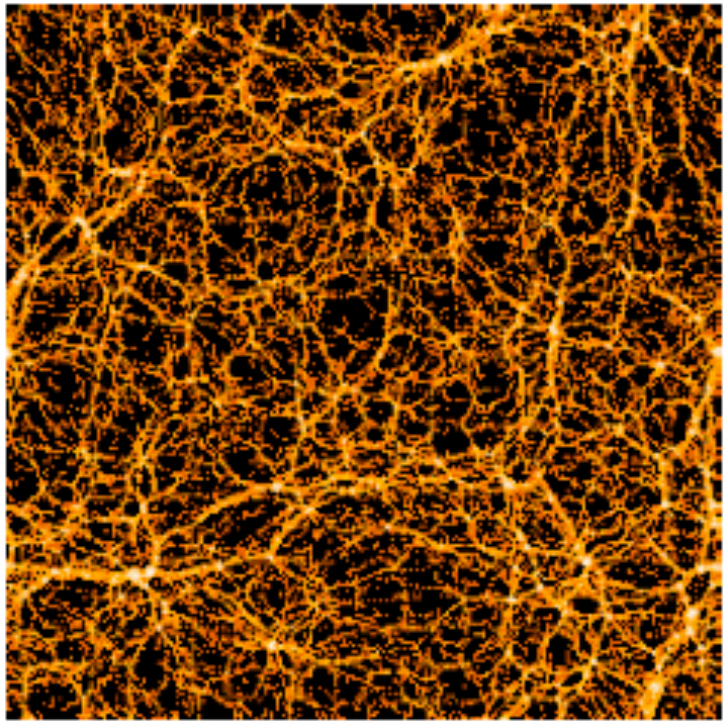

Coles & Chiang , Nature 2000

# Non-Gaussianity: phase information

The Power spectrum is the same (no amplitude has been touched), but the morphology is completely different!!!

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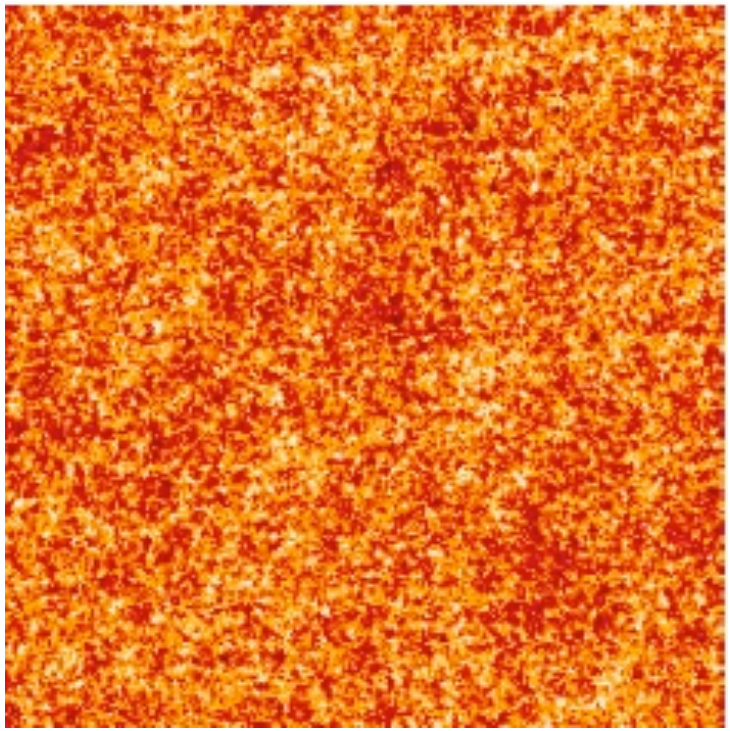

Coles & Chiang , Nature 2000

# Primordial non-Gaussianity and Inflation

NON-GAUSSIANITY IS A KEY OBSERVABLE TO DISCRIMINATE AMONG COMPETING SCENARIOS FOR THE GENERATION OF COSMOLOGICAL PERTURBATIONS

Different Inflationary models $\Longrightarrow$ different levels and types of non-Gaussianity

Standard inflation $\Rightarrow$ $f_{NL} \sim 0$, i.e. Gaussianity

BUT

Curvaton Inflation,
Multi-field inflation,
Ghosts, Topological Defects,
...

$\Rightarrow$ $f_{NL} << 1$
$f_{NL} >> 1$

$f_{NL} = 0$: GAUSSIAN UNIVERSE AT PRIMORDIAL TIMES

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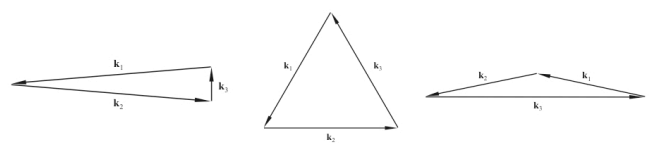
$$B_\Phi(k_1, k_2, k_3) \equiv f_{\rm NL}\ F(k_1, k_2, k_3)$$



# Primordial non-Gaussianity and Inflation

NON-GAUSSIANITY IS A KEY OBSERVABLE TO DISCRIMINATE AMONG COMPETING SCENARIOS FOR THE GENERATION OF COSMOLOGICAL PERTURBATIONS

Different types of PNG $\Longrightarrow$ different effects on the observable signals

FOR THE MOMENT, ALWAYS PRIMORDIAL NON-GAUSSIANITY OF THE **LOCAL TYPE**

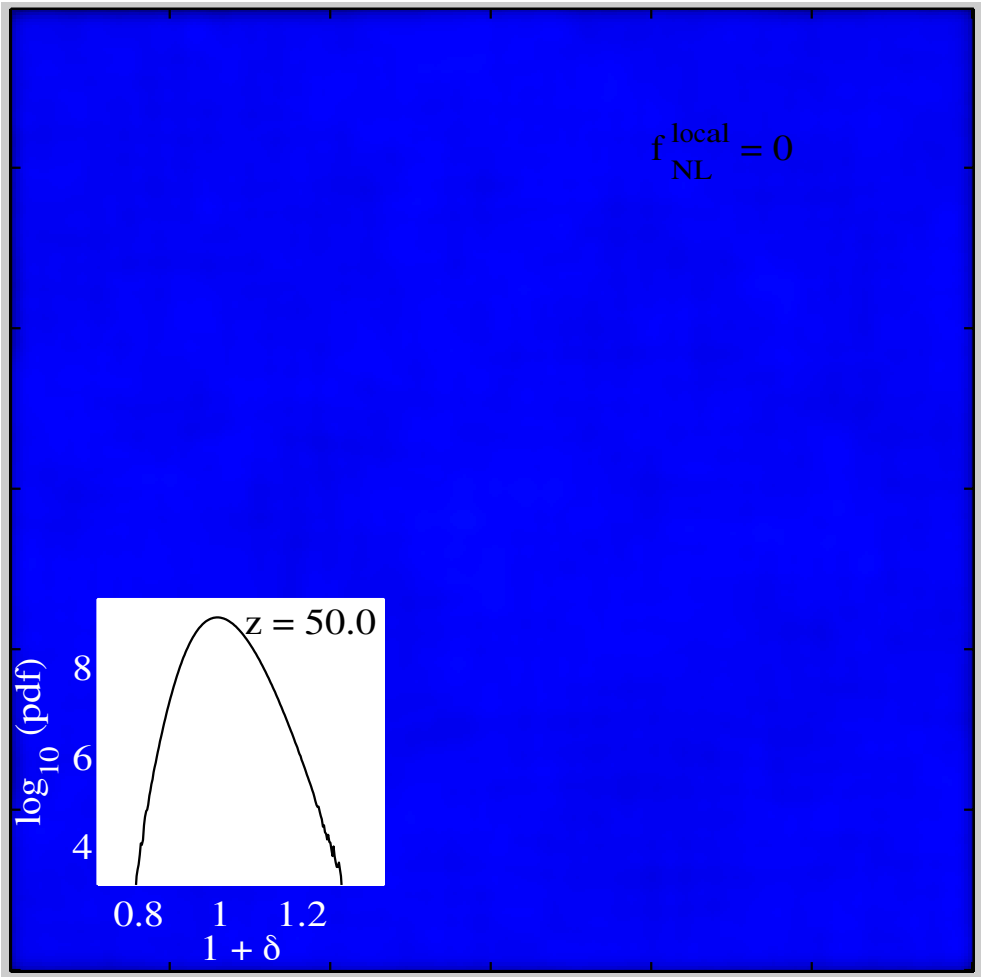
Phenomenological parameterization (local type):

$$\begin{aligned}\Phi(\mathbf{x}) &= \Phi_G(\mathbf{x}) + \Phi_{\rm NL}(\mathbf{x}) \\ &= \Phi_G(\mathbf{x}) + f_{\rm NL}^{\rm local}(\Phi_G^2 - \langle\Phi_G^2\rangle) + g_{\rm NL}^{\rm local}\Phi_G^3 \ ,\end{aligned}$$

# The Large Scale Structure

Pillepich et al. 2010
2010MNRAS.402,191P

250 $h^{-1}$ Mpc




$f_{NL} = 0$

**Suite of 12 runs with Gaussian and non-Gaussian initial conditions!**
**(with Gadget-2, by Springel)**

- Dark Matter only
- $1024^3$ particles
- $L_{box}$ = 1200 Mpc $h^{-1}$ (and 150 Mpc $h^{-1}$)
- $M_{part}$ = $1.2 \times 10^{11}$ $M_{sun}$ $h^{-1}$ (and $2.4 \times 10^8$ )
- $f_{NL}$ = -80, ...., +750
- WMAP5 cosmology
- FOF Haloes

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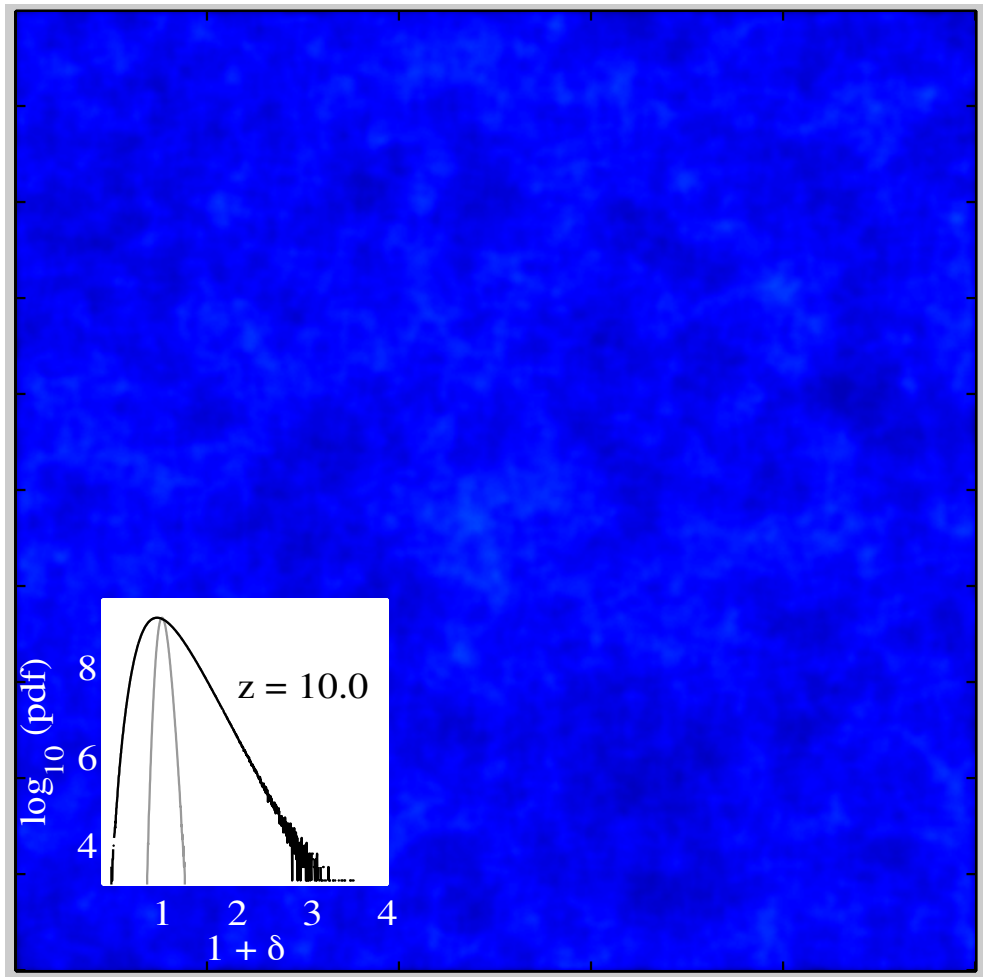


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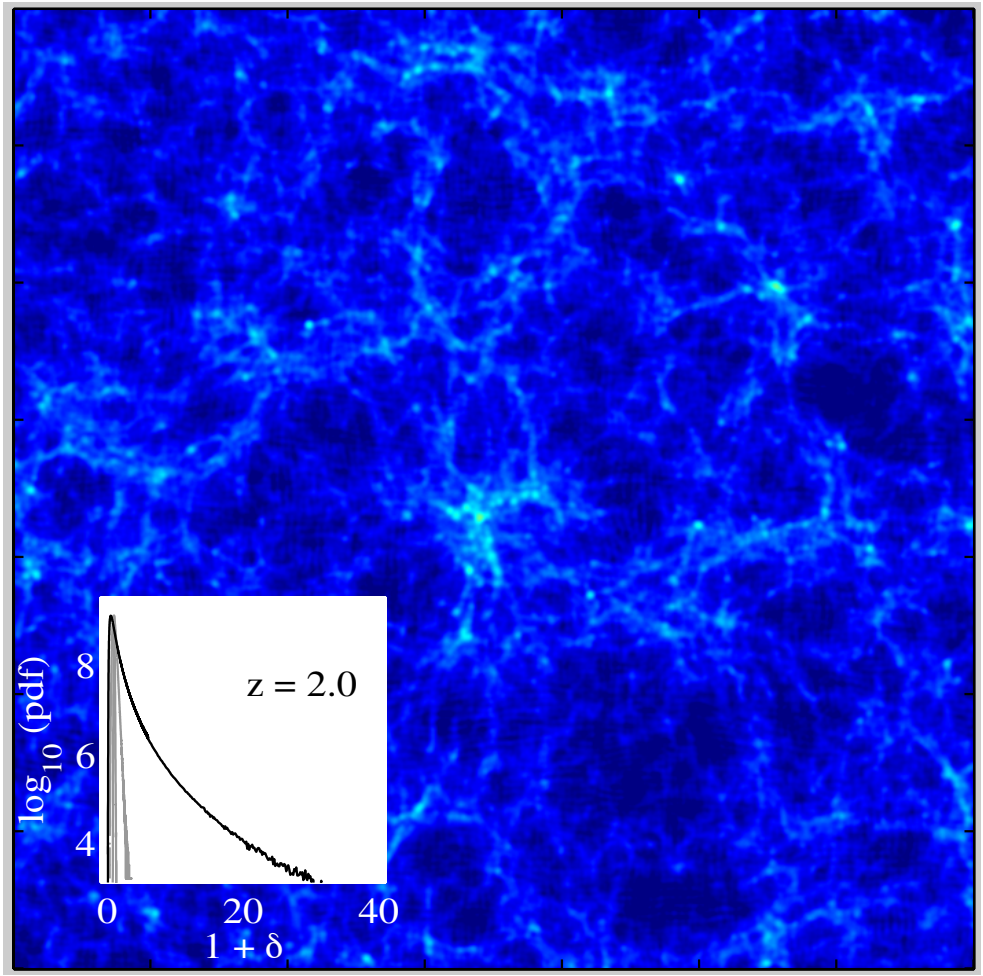


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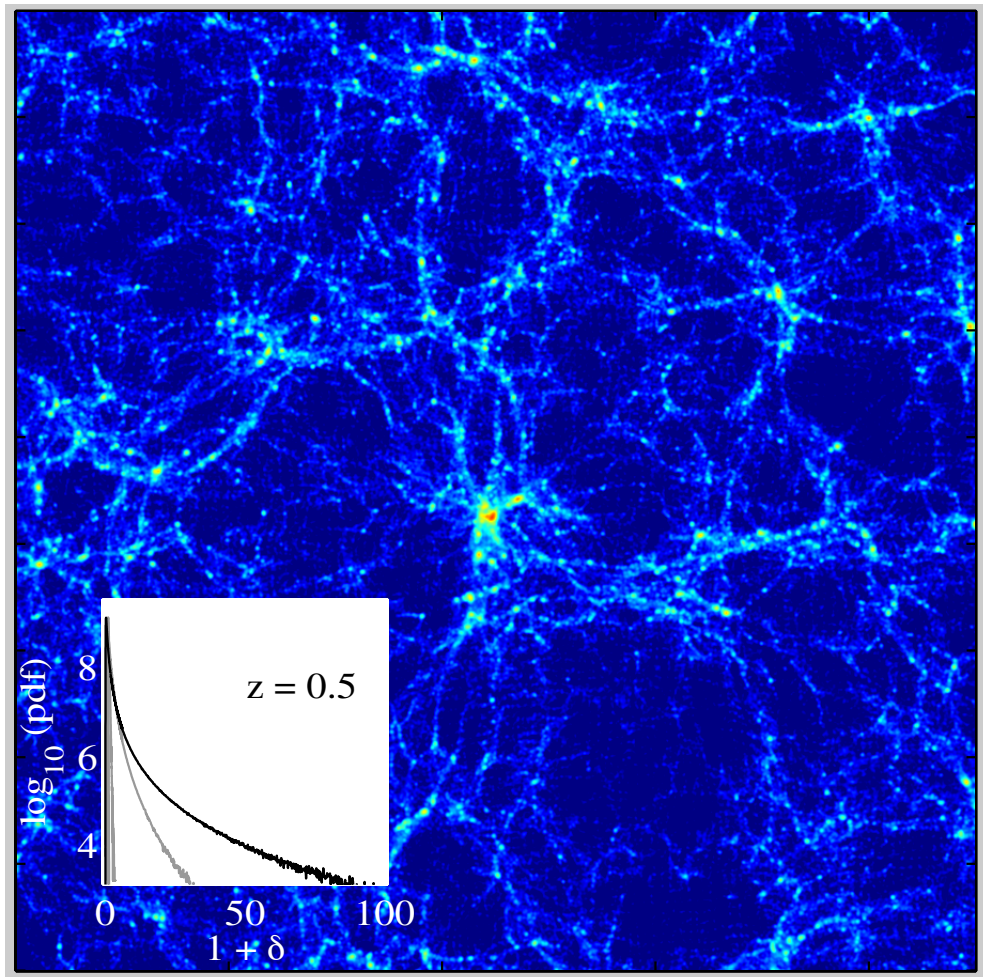


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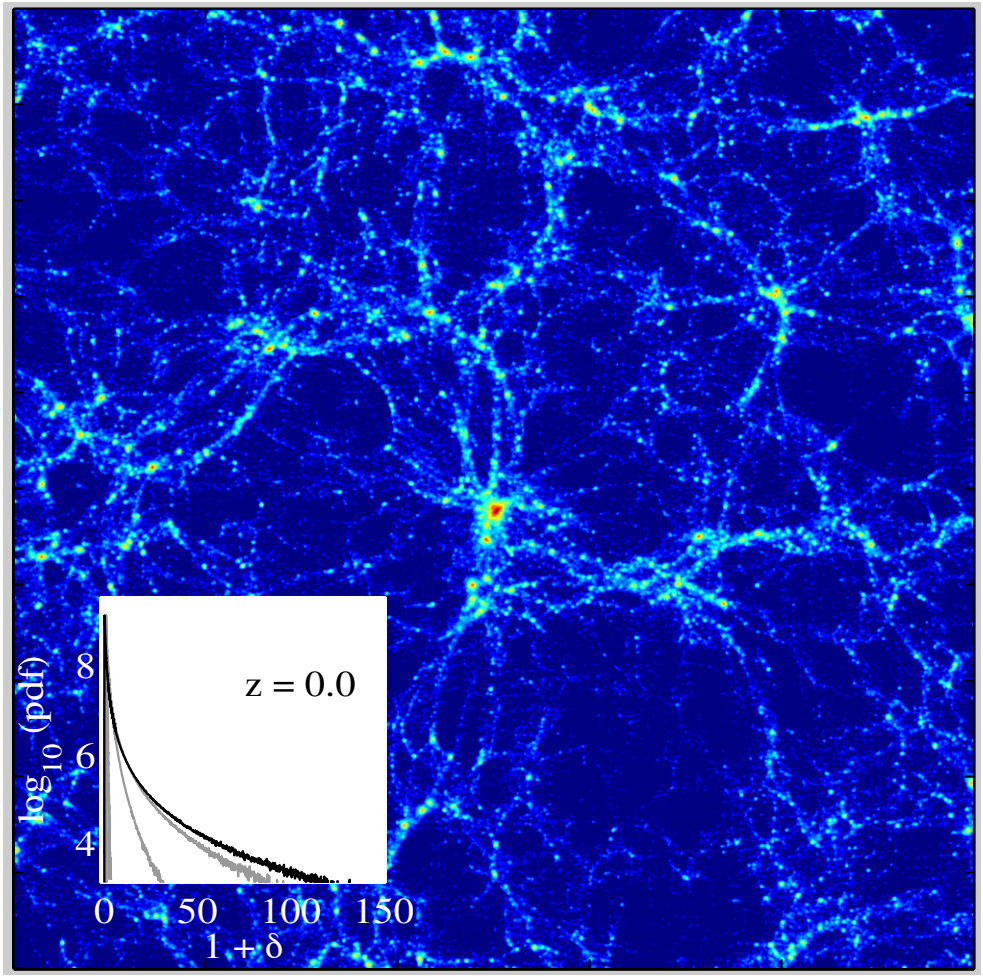


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# PNG in N-body sims

Pillepich et al. 2010
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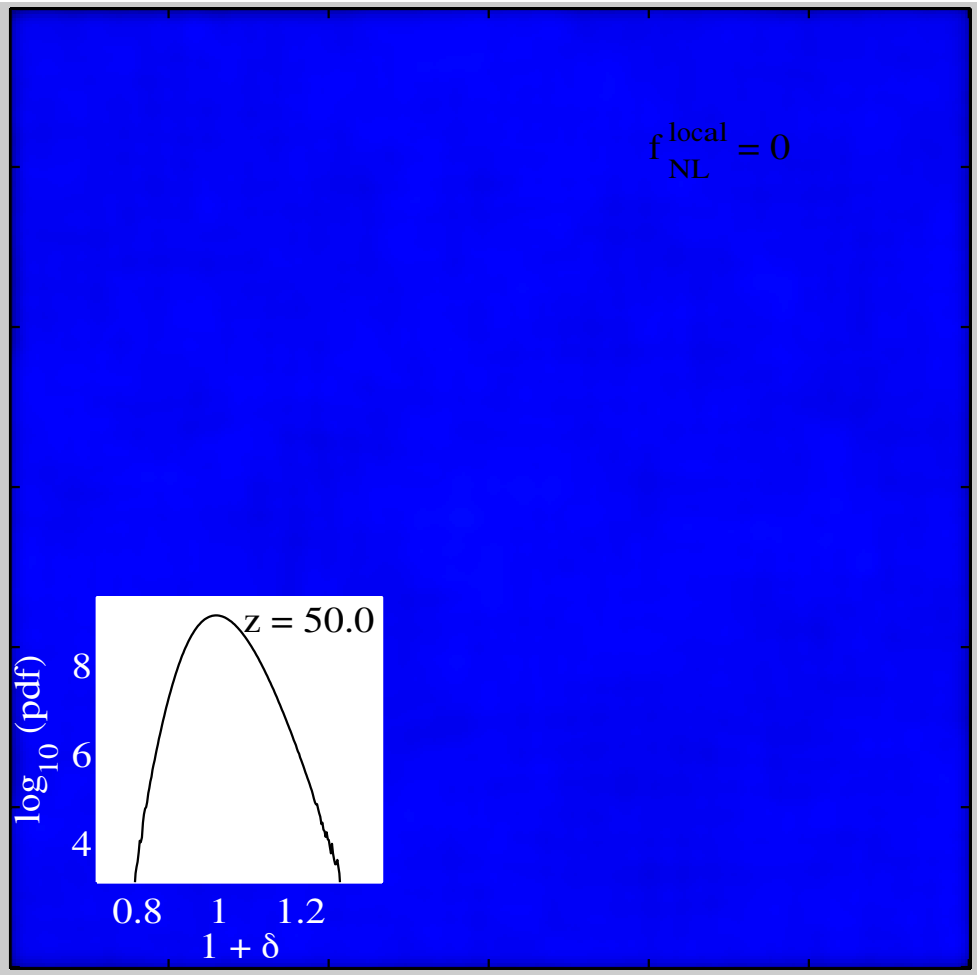
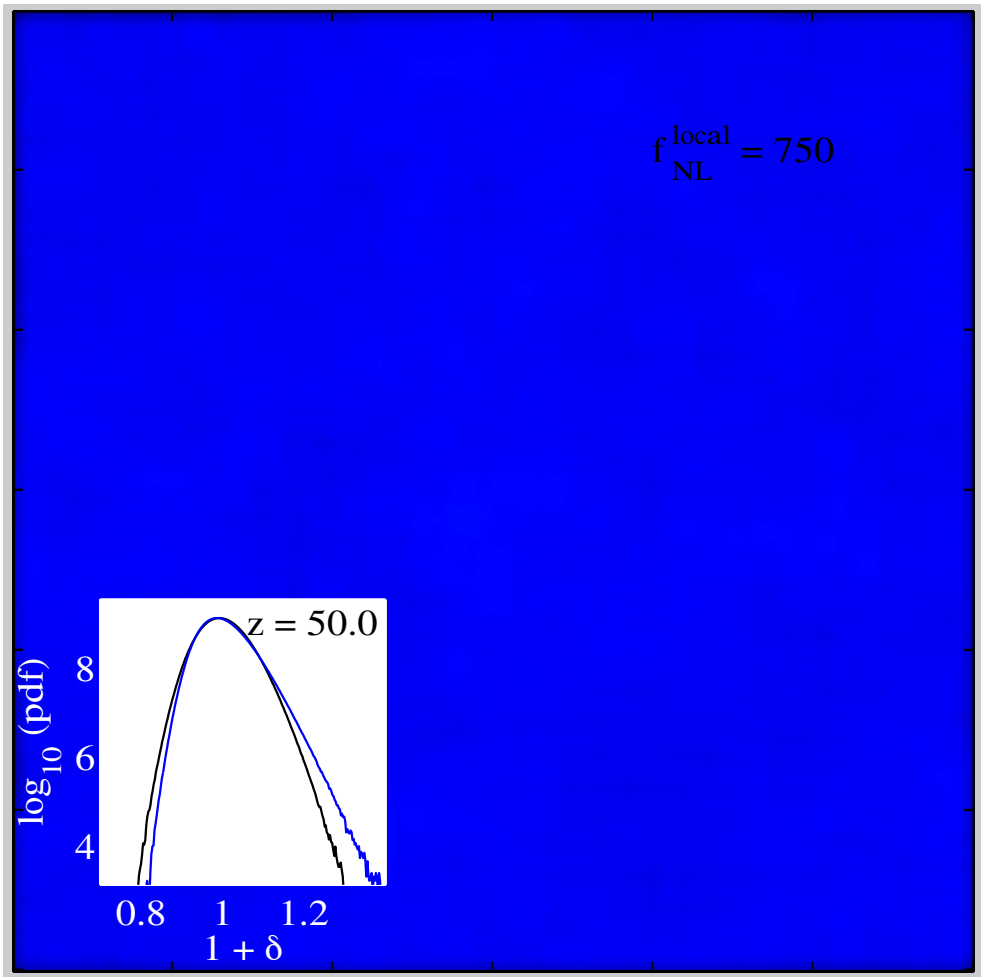



$f_{NL} = 750$



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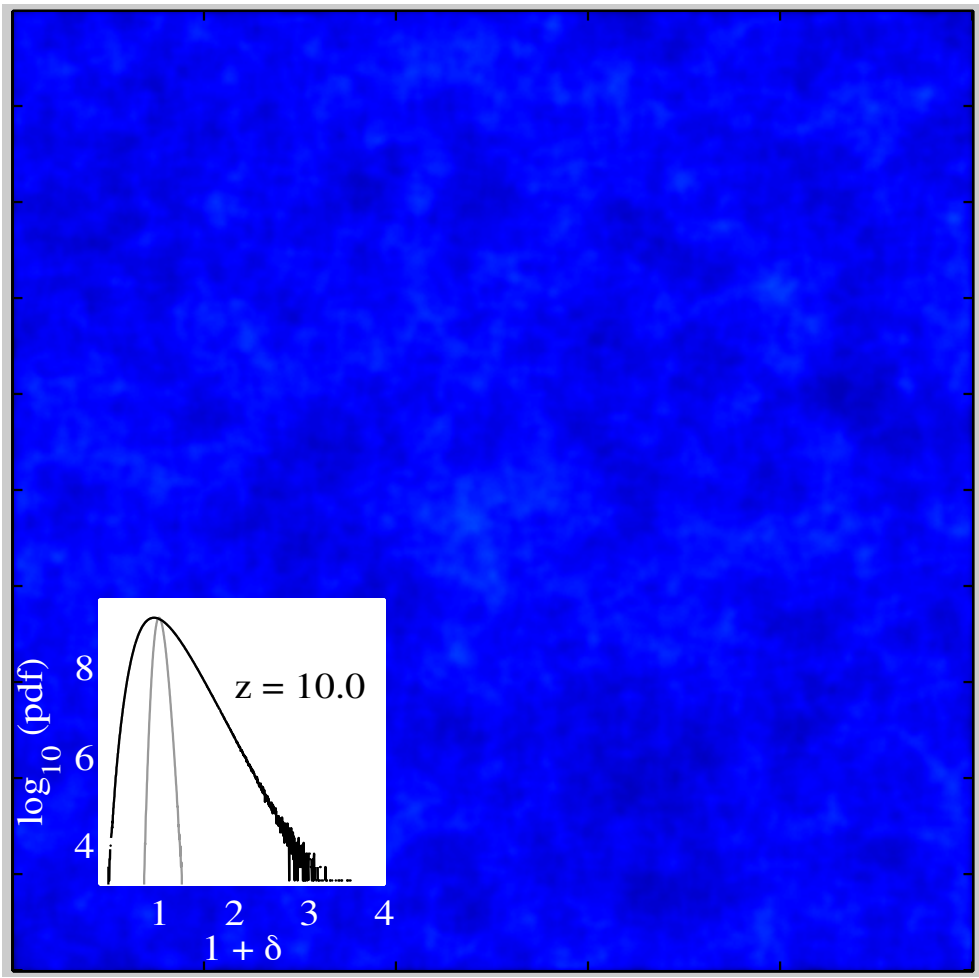


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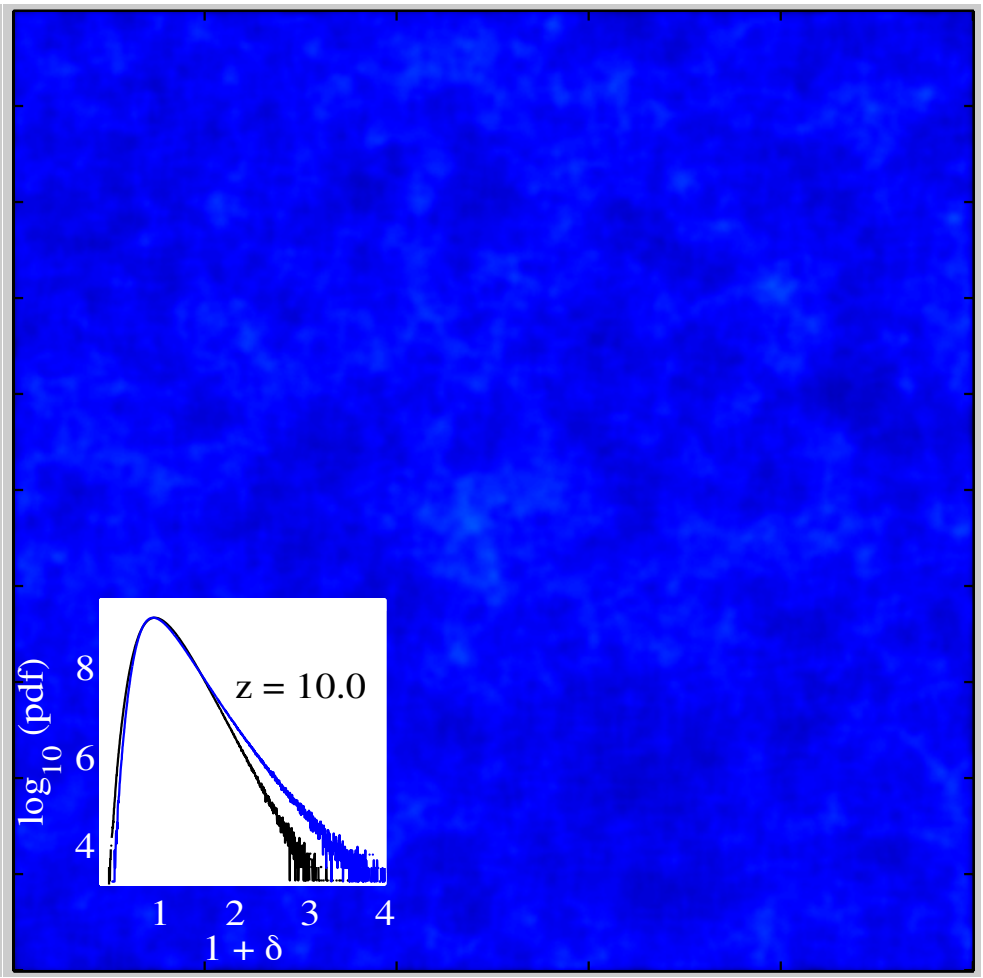

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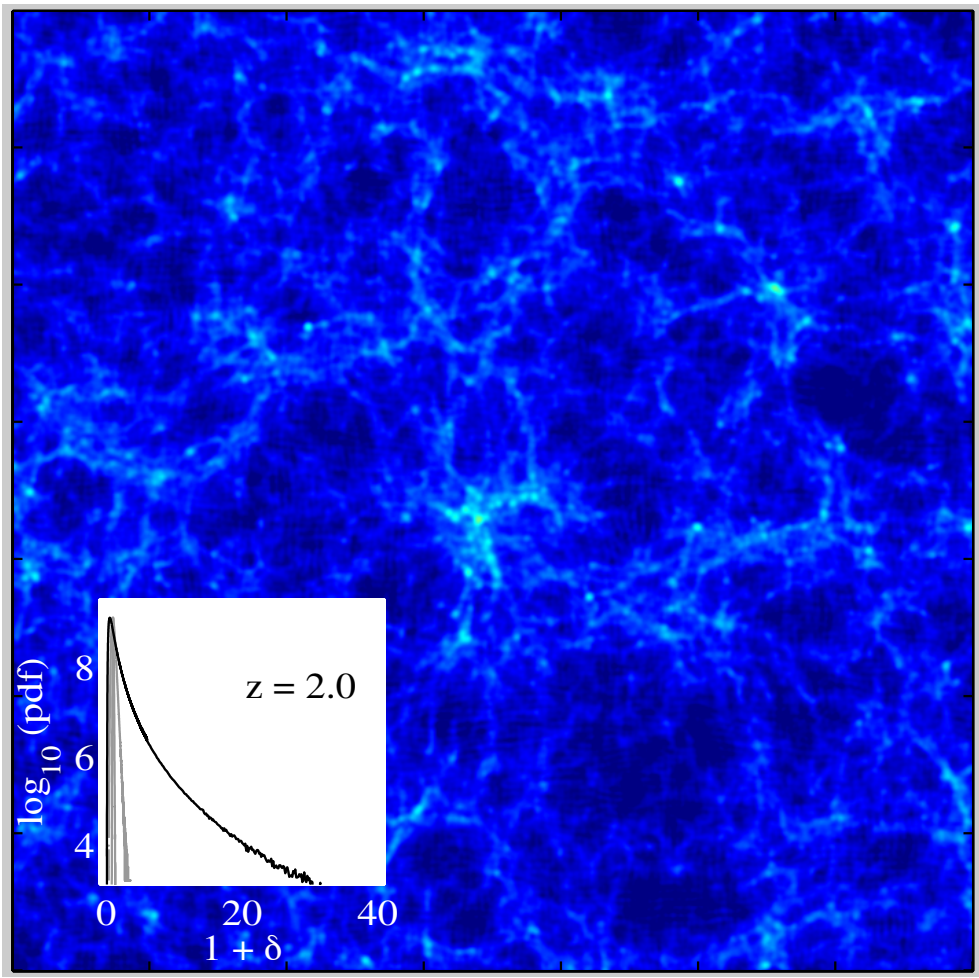


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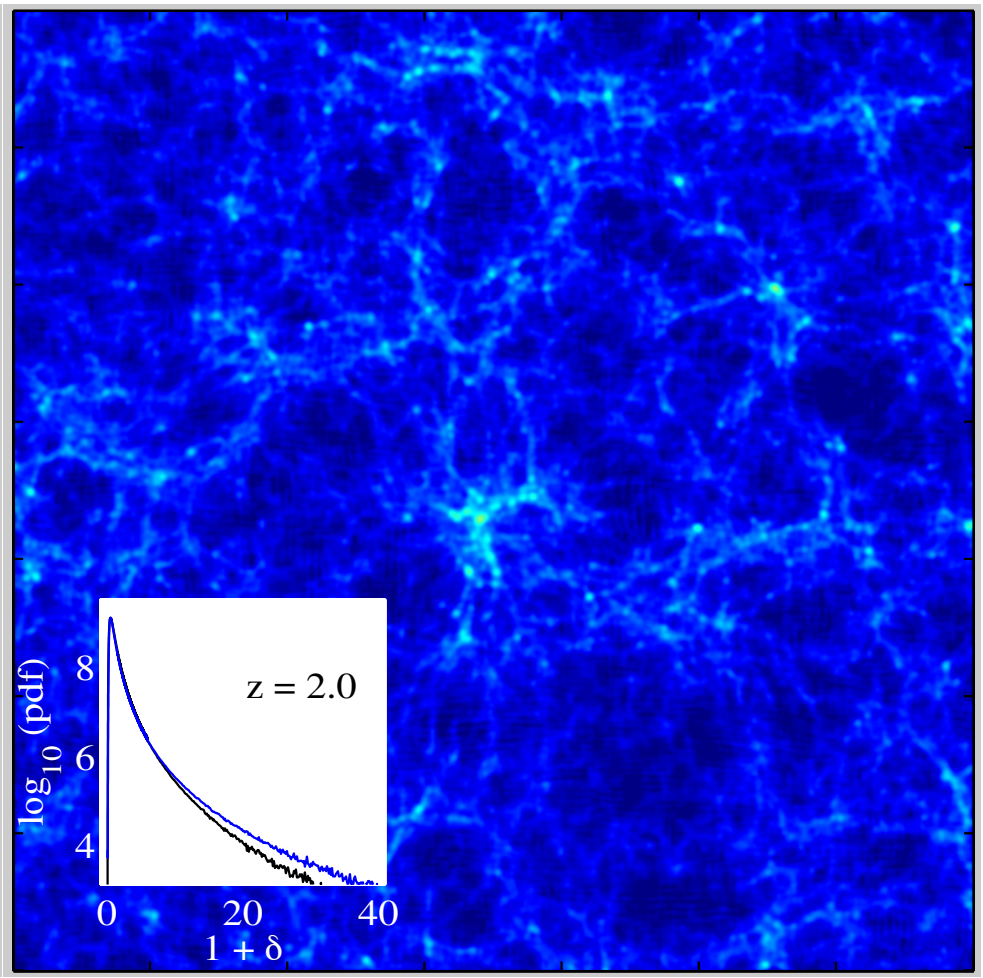

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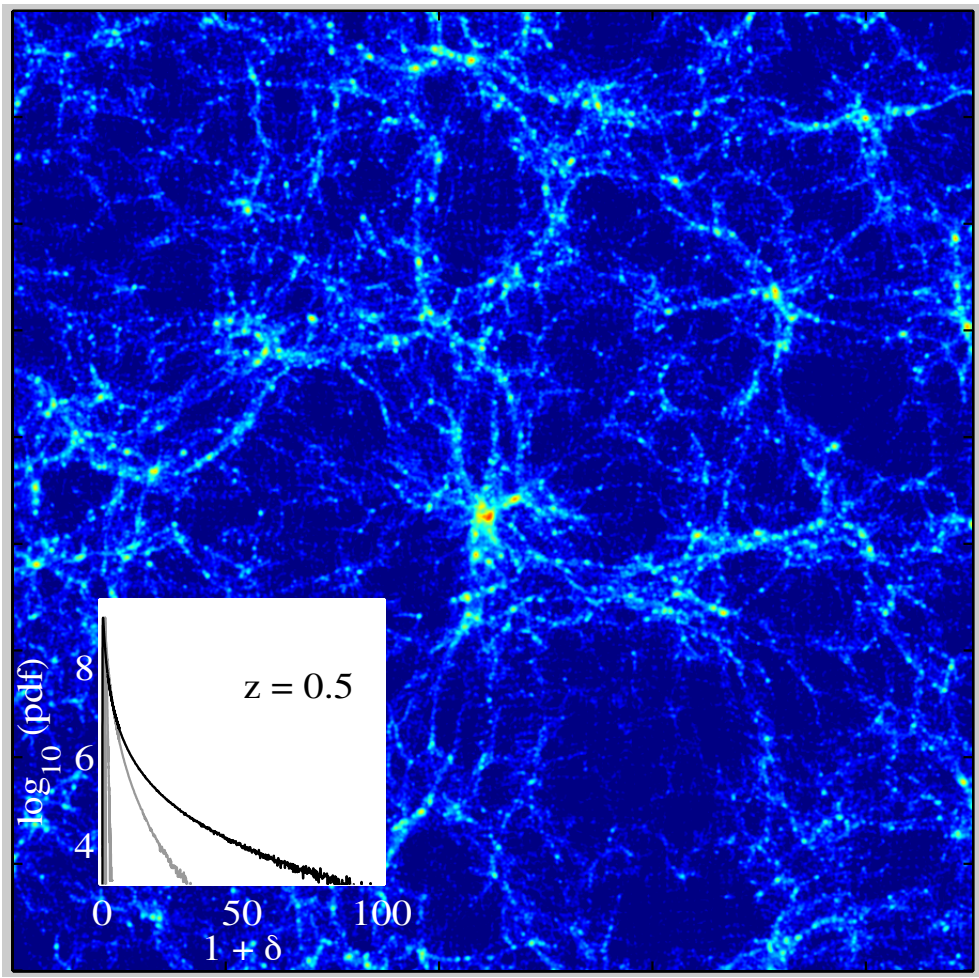


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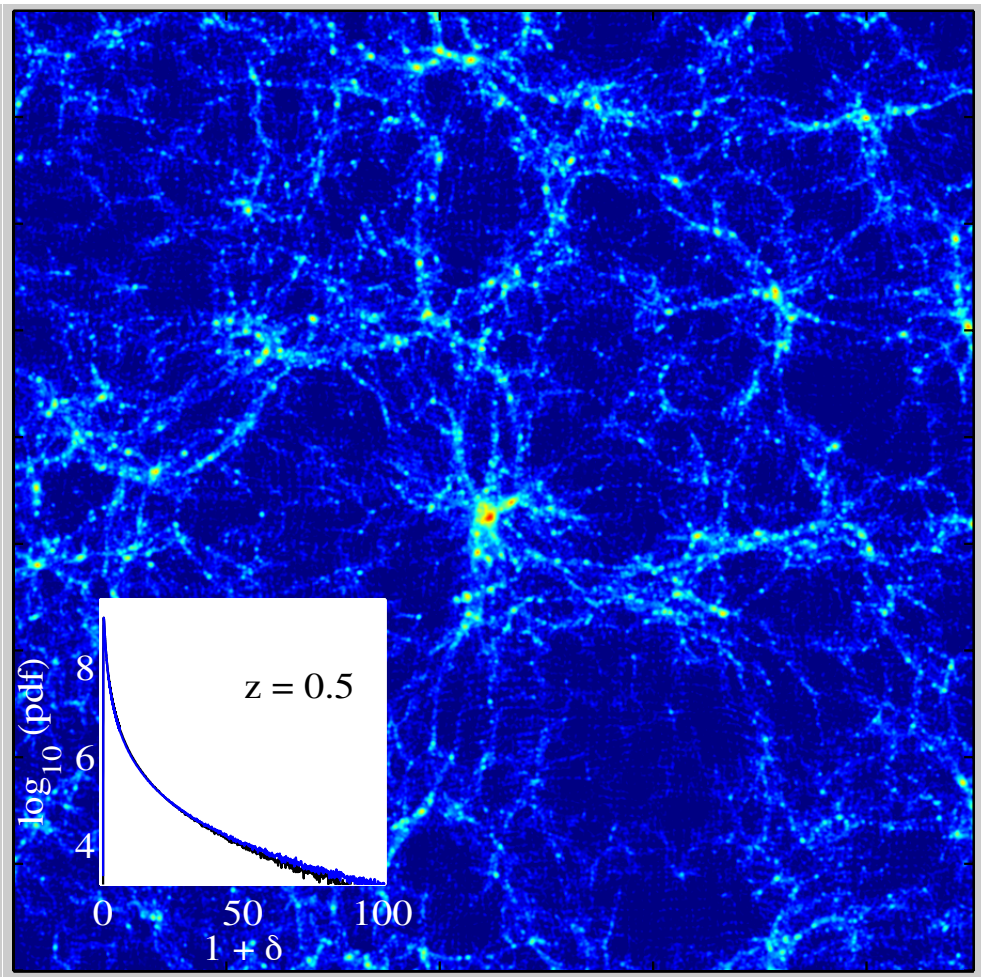

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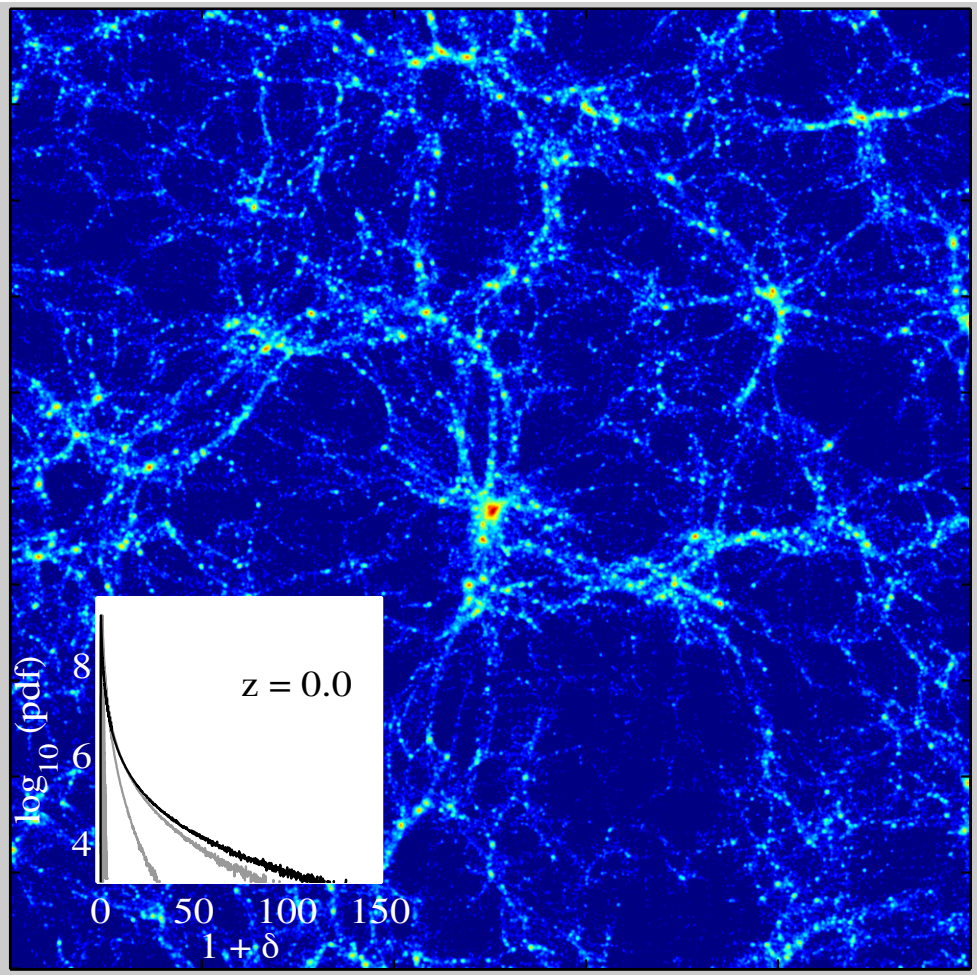


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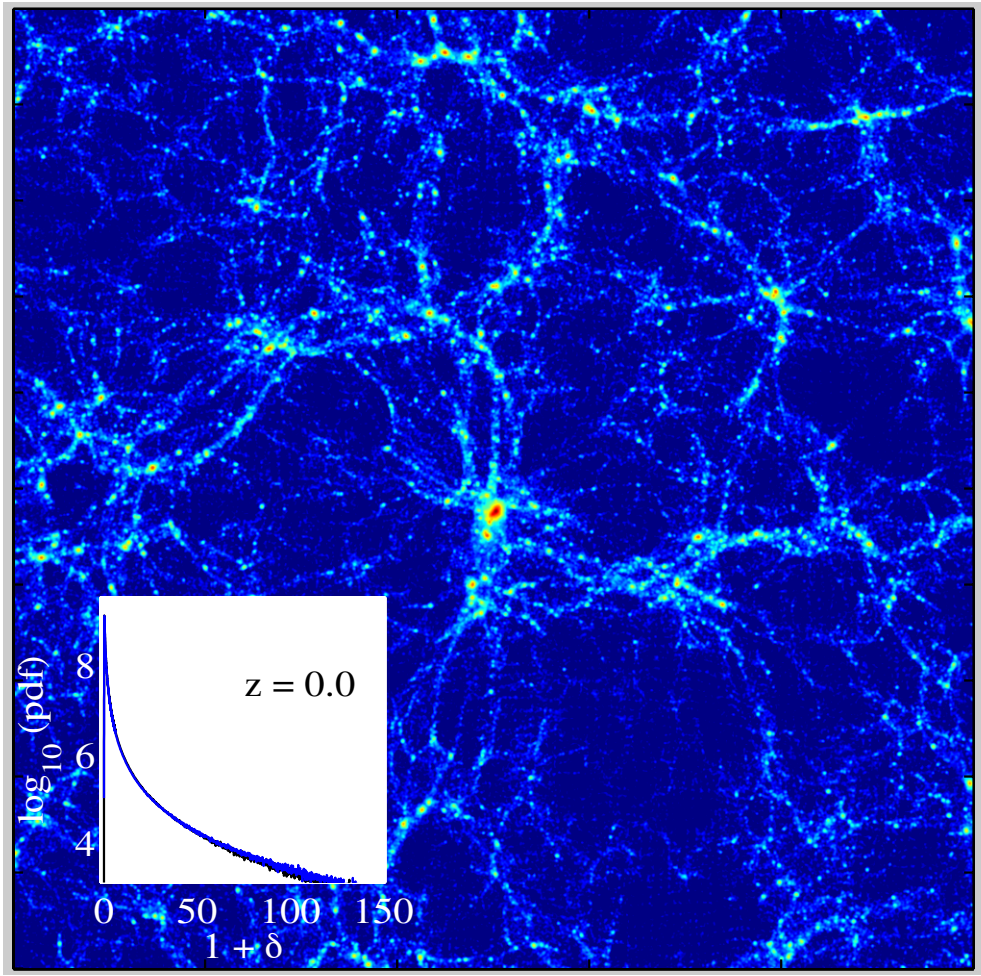

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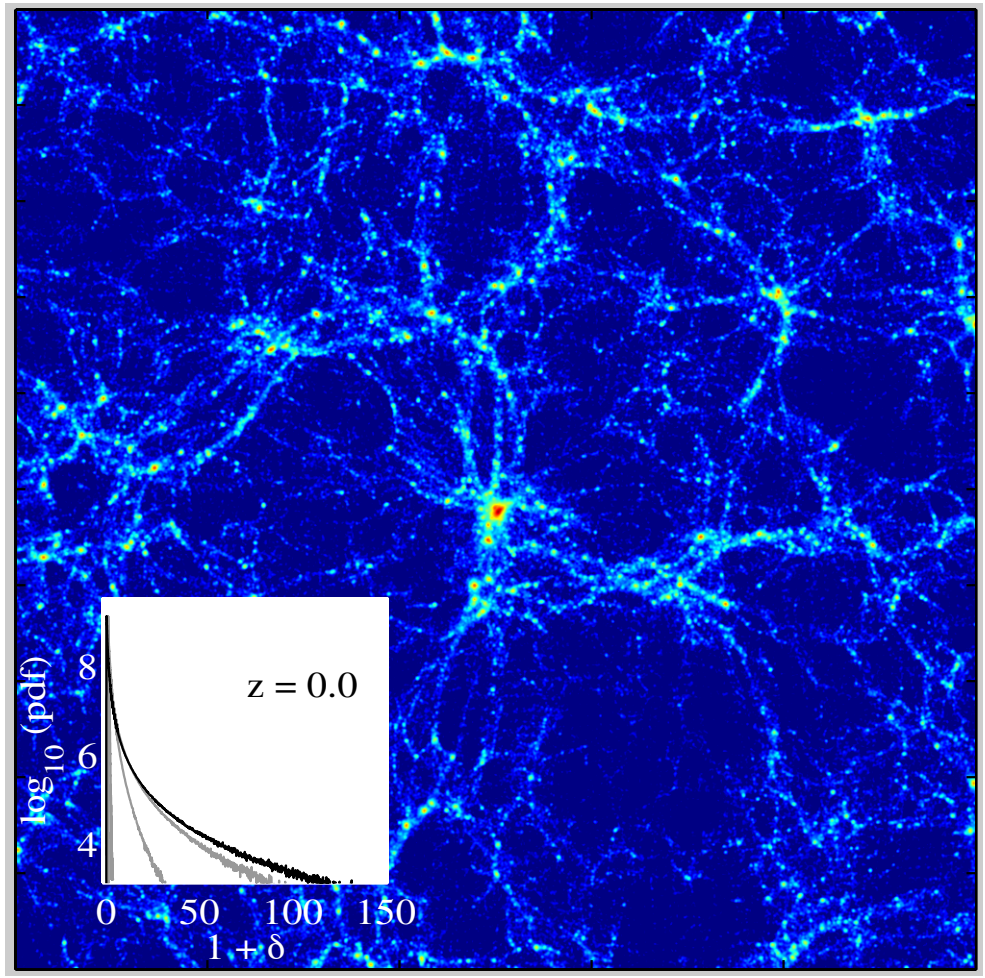
250 $h^{-1}$ Mpc

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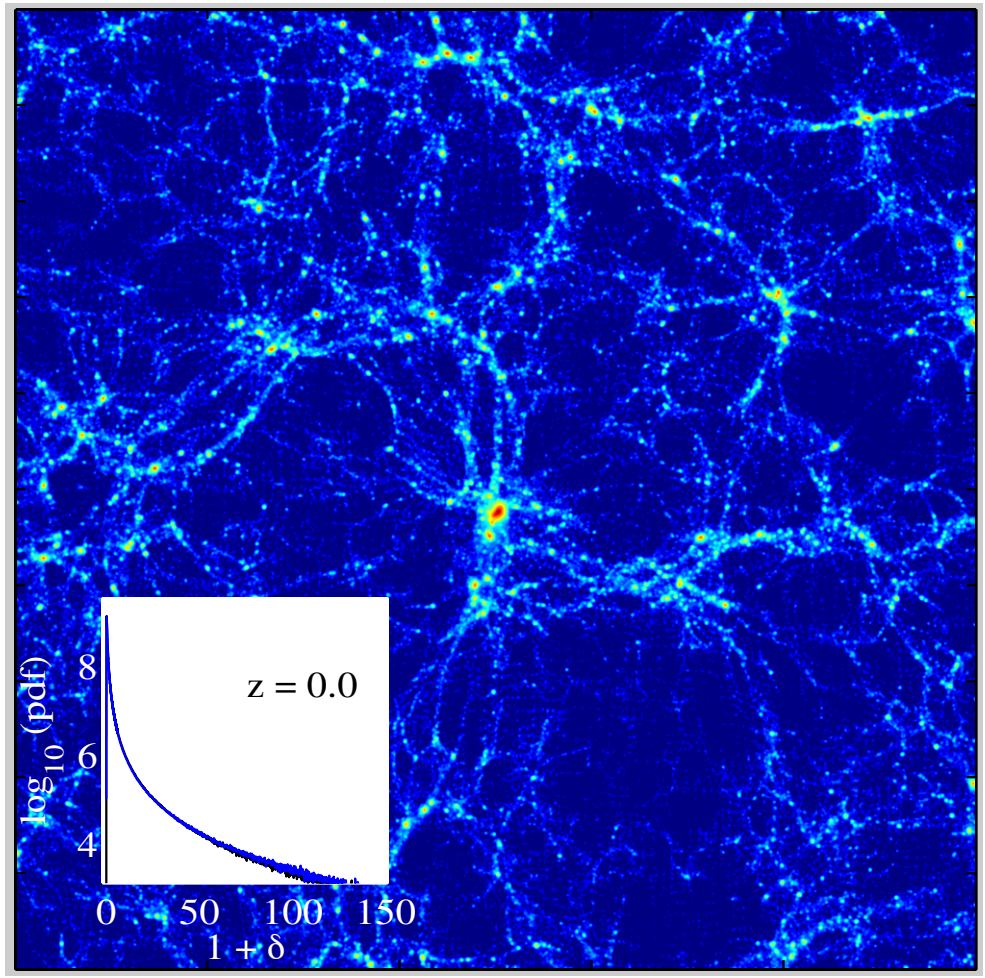


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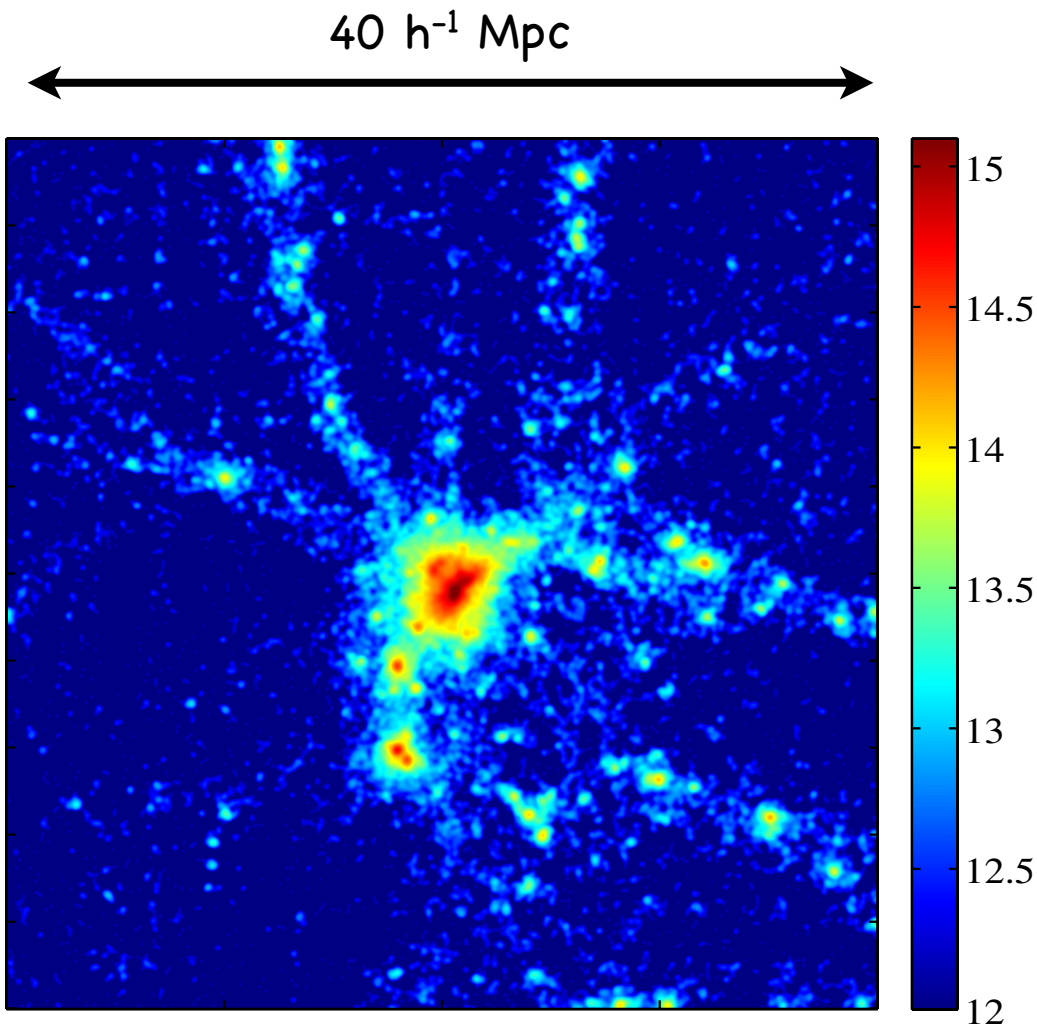
# A massive galaxy cluster

Pillepich et al. 2010
2010MNRAS.402,191P

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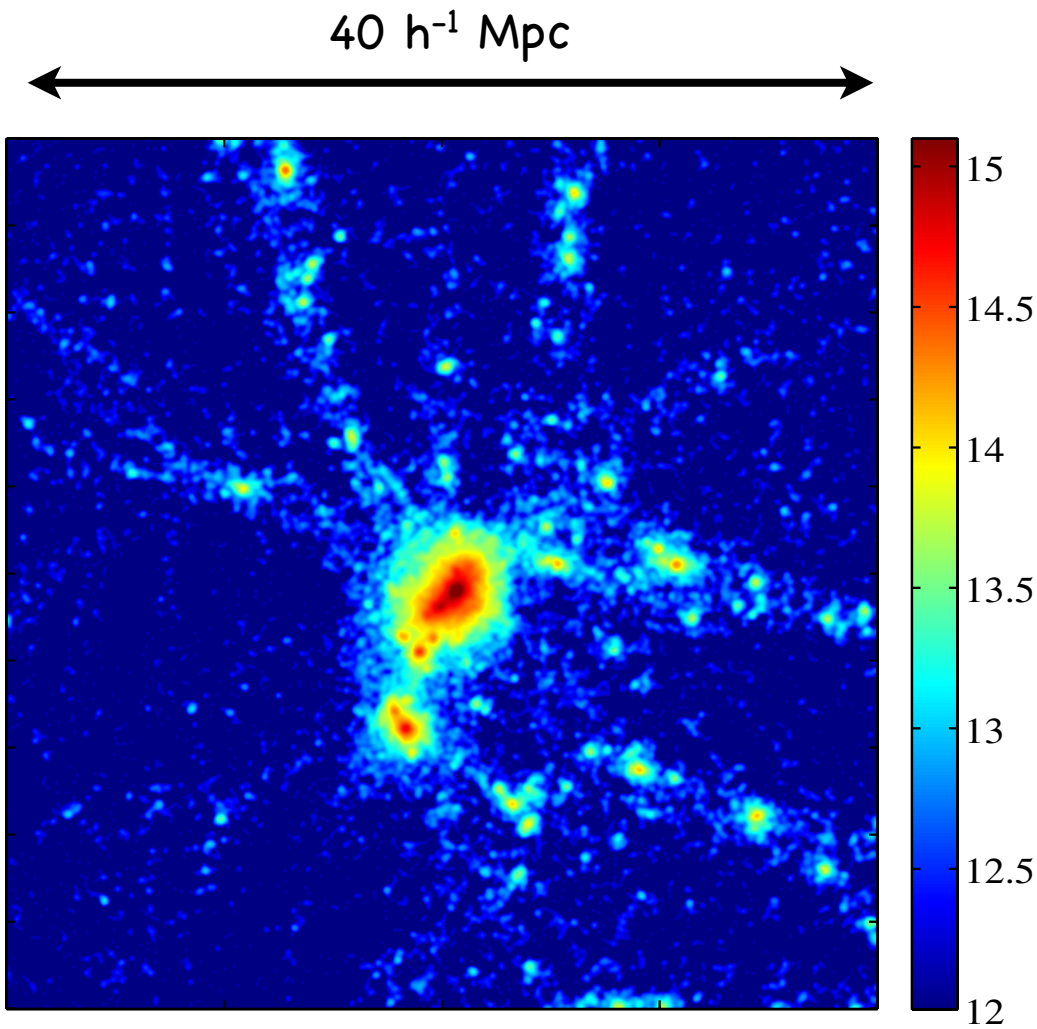


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# Effects of (local) primordial non-Gaussianity

## A) ON THE SMOOTHED DENSITY FIELD, $\delta(x,t)$

1. Pdf of $\delta(\mathbf{x},t)$
2. n-point statistics with n>2 (bispectrum, trispectrum, ...)
3. Topology of the field
4. Non Linear Powerspectrum of $\delta(\mathbf{k},t)$ at $k > 0.1$ h/Mpc

## B) ON THE LSS, I.E. COLLAPSED OBJECTS

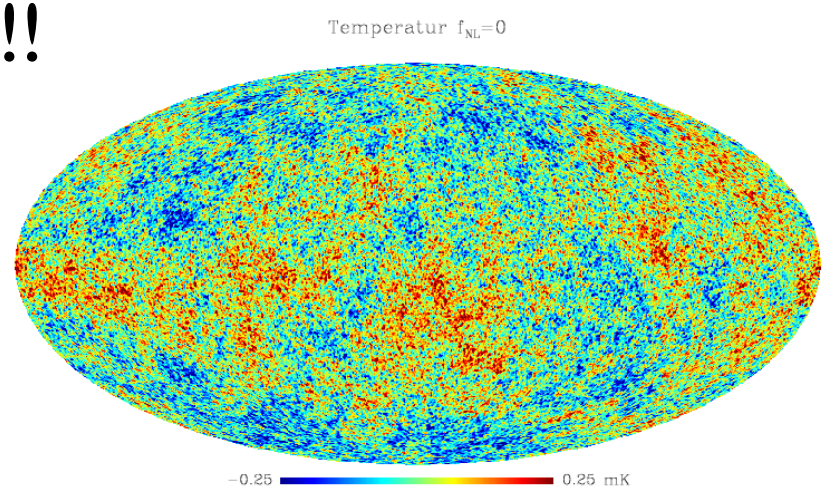
1. Dark Matter Halo Mass Function
2. Dark Matter Halo Bias, i.e. clustering
3. Abundance of voids
4. Density profiles of DM Haloes
5. ....

# Effects of (local) primordial non-Gaussianity

**A) ON THE SMOOTHED DENSITY FIELD, δ(x,t) or its tracers**

1. Pdf of δ(**x**,t)
2. n-point statistics with n>2 (bispectrum, trispectrum, ...)
3. Topology of the field

CMB!!!

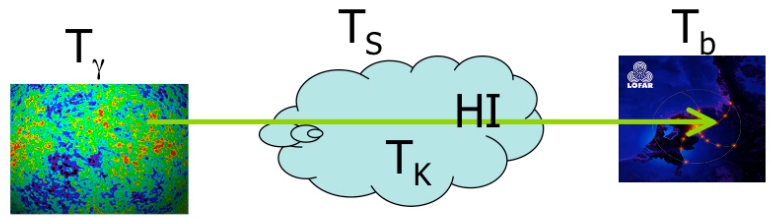


# Effects of (local) primordial non-Gaussianity

**A) ON THE SMOOTHED DENSITY FIELD, δ(x,t) or its tracers**

1. Pdf of δ(**x**,t)
2. n-point statistics with n>2 (bispectrum, trispectrum, ...)
3. Topology of the field

21cm Background!!! Pillepich et al. 2007



...

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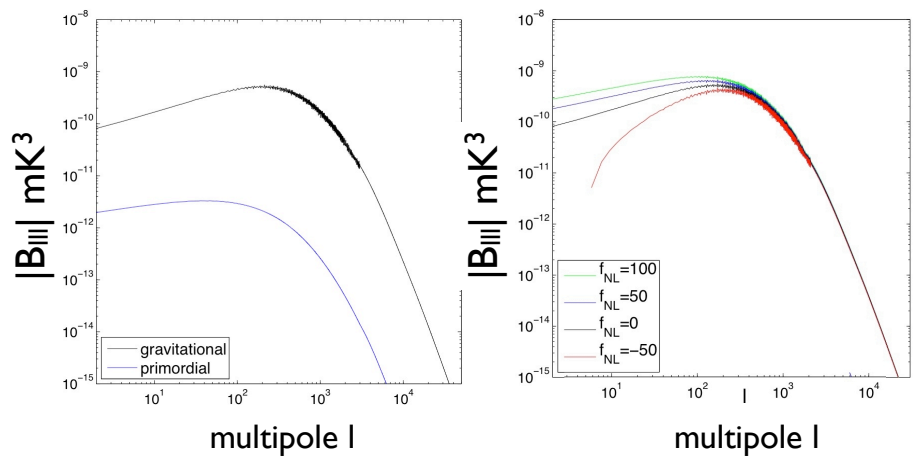


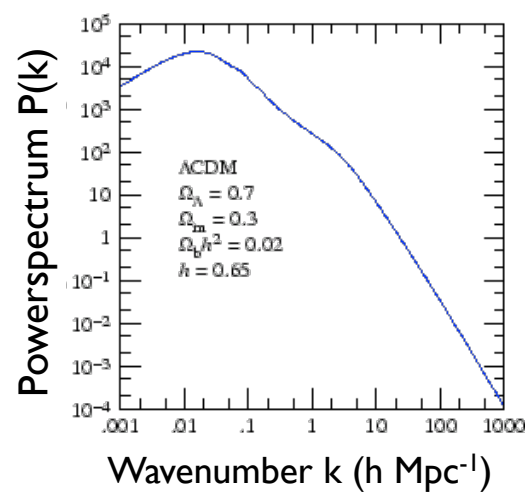
# Effects of (local) primordial non-Gaussianity

**A) ON THE SMOOTHED DENSITY FIELD, δ(x,t) or its tracers**

1. Non Linear Powerspectrum of δ(**k**,t) at k > 0.1 h/Mpc

e.g. Weak lensing!!

Pillepich et al. 2010



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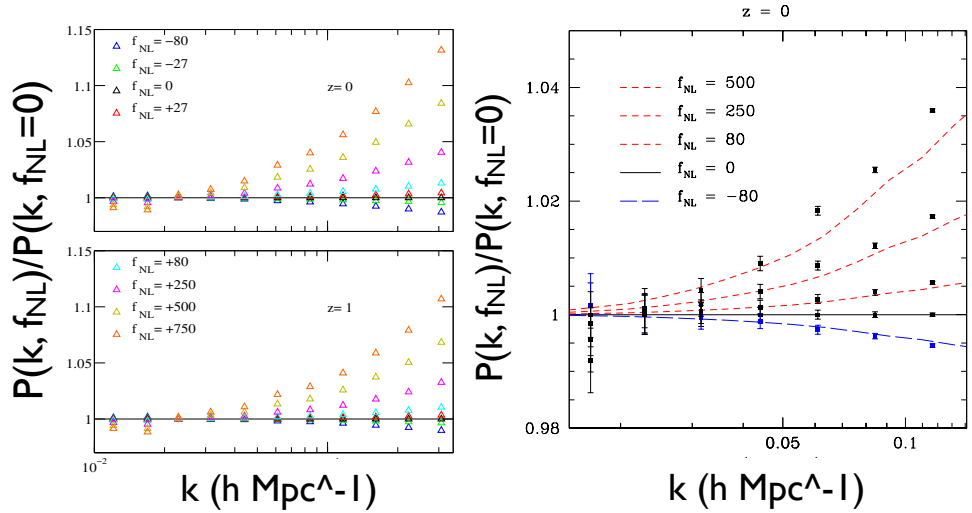

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1. Pdf of $\delta(\mathbf{x},t)$
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3. Topology of the field
4. Non Linear Powerspectrum of $\delta(\mathbf{k},t)$ at k > 0.1 h/Mpc

## B) ON THE LSS, I.E. COLLAPSED OBJECTS

1. Dark Matter Halo Mass Function
2. Dark Matter Halo Bias, i.e. clustering
3. Abundance of voids
4. Density profiles of DM Haloes
5. ....

# Effects of (local) primordial non-Gaussianity

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Dalal et al. 2008
Matarrese & Verde 2008
Slosar et al. 2008
Afshordi & Tolley 2008
Mc Donald 2008
LoVerde et al. 2008
Taruya et al. 2008
Valageas 2009
Maggiore & Riotto 2009
Giannantonio & Porciani 2009
Sefusatti et al. 2006, 2007, ..
....

# Effects of (local) primordial non-Gaussianity

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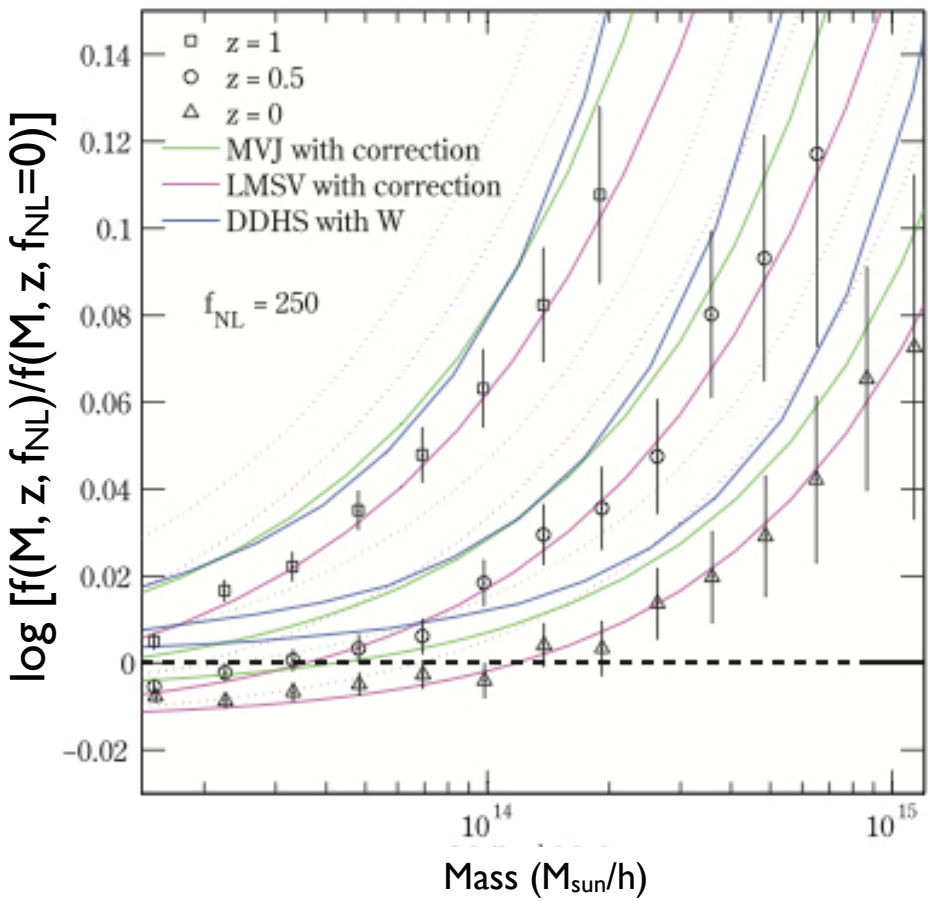
Kang et al. 2007
Grossi et al. 2007
Dalal et al. 2008
Desjacques et al. 2008
Grossi et al. 2009
.....

# Effects of (local) primordial non-Gaussianity

Dark Matter Halo Mass Function

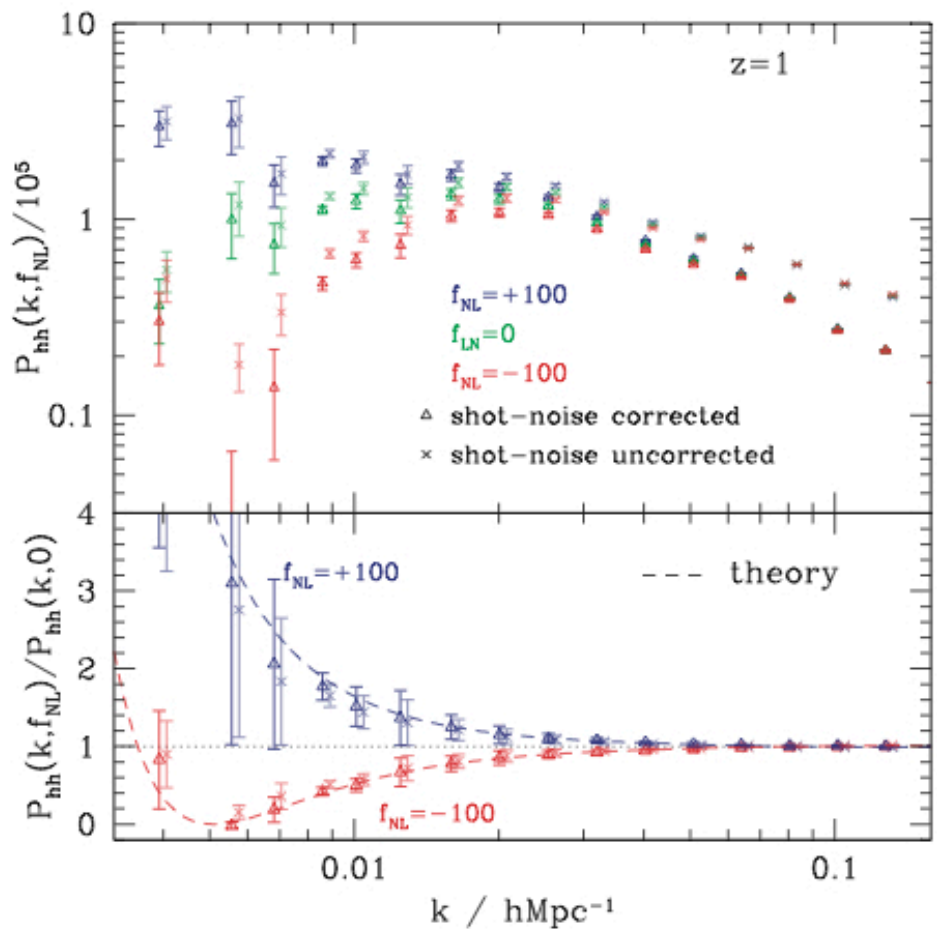



Pillepich et al. 2010

# Effects of (local) primordial non-Gaussianity

Dark Matter Halo Bias

$$b_{\rm hh}(k,M,z) = \sqrt{\frac{P_{\rm hh}(k,M,z)}{P(k,z)}}$$




Desjacques et al. 2009

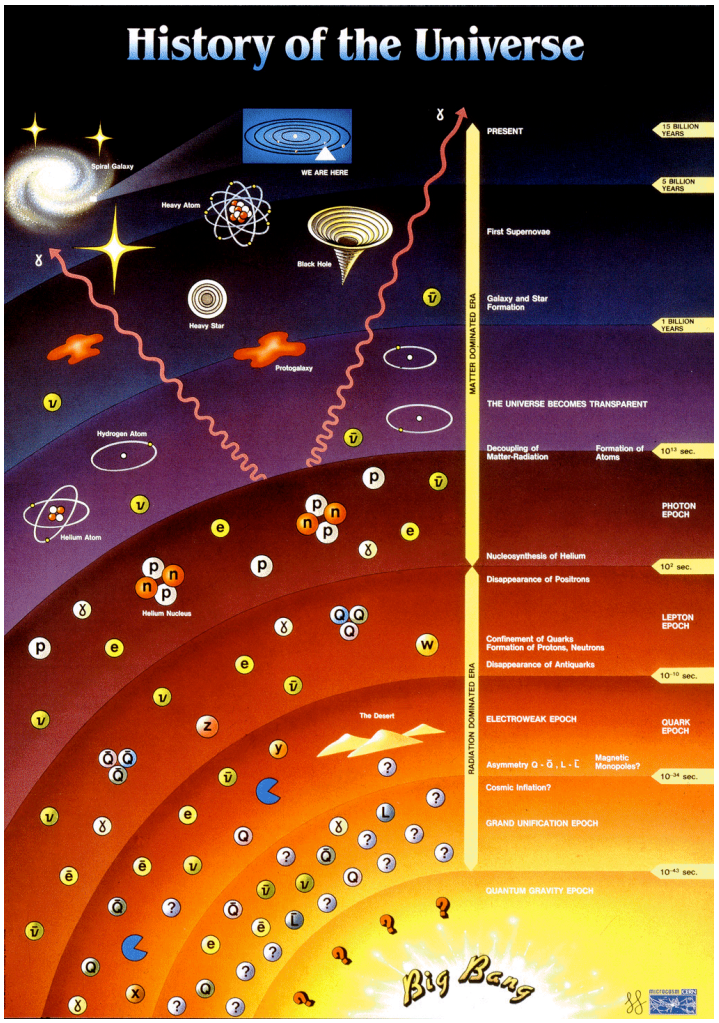
# Current Status ...

## Now)

| Constraints from the CMB | | |
|---|---|---|
| Temperature Bispectrum | $-10 < f_{\rm NL}^{\rm local} < 74$ | WMAP7, Komatsu et al. (2010) |
| | $[illegible] < f_{\rm NL}^{\rm local} < [illegible]$ | WMAP5, Komatsu et al. (2009) |
| | $11 < f_{\rm NL}^{\rm local} < 23.7$ | WMAP5, Smidt et al. (2009) |
| Minkowski functionals | $-178 < f_{\rm NL}^{\rm local} < 64$ | WMAP5, Komatsu et al. (2009) |
| Wavelet decomposition | $-8 < f_{\rm NL}^{\rm local} < 111$ | WMAP5, Curto et al. (2008) |
| Temperature Bispectrum | $27 < f_{\rm NL}^{\rm local} < 147$ | WMAP3, Yadav and Wandelt (2008) |
| Minkowski functionals | $-70 < f_{\rm NL}^{\rm local} < 91$ | WMAP3, Hikage et al. (2008) |
| *Pdf* of $\delta T_{\rm CMB}$ | $23 < f_{\rm NL}^{\rm local} < 75$ | WMAP3, Jeong and Smoot (2007) |
| Temperature Bispectrum | $-214 < f_{\rm NL}^{\rm equilateral} < 466$ | WMAP7, Komatsu et al. (2010) |
| | $-125 < f_{\rm NL}^{\rm equilateral} < 435$ | WMAP5, Senatore et al. (2010) |
| | $-256 < f_{\rm NL}^{\rm equilateral} < 332$ | WMAP3, Creminelli et al. (2006) |
| | $-366 < f_{\rm NL}^{\rm equilateral} < 238$ | WMAP1, Creminelli et al. (2006) |
| Constraints from the LSS | | |
| Clustering of LRGs & quasars | $-29 < f_{\rm NL}^{\rm local} < 69$ | SDSS, Slosar et al. (2008) |
| Clustering of Radio Sources, LRGs & quasars | $5 < f_{\rm NL}^{\rm local} < 84$ | NVSS, SDSS DR7, Xia et al (2011) |

95% C.L.

# Future) ... and Future Perspectives




DES: $\sigma(f_{NL}) \sim 5\text{-}9$ (~2015)

counts in cells of galaxy-clusters, Cunha et al. 2010

weak lensing and 2D clustering of galaxies, Giannantonio et al. 2011

EUCLID: $\sigma(f_{NL}) \sim 3\text{-}5$ (>2020)

weak lensing and 2D clustering of galaxies, Giannantonio et al. 2011

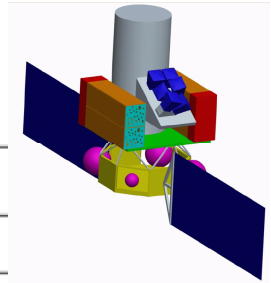
eROSITA!!!

21cm: $\sigma(f_{NL}) \sim 1$ (20??)

Planck: $\sigma(f_{NL}) \sim 5$ (Jan 2013)

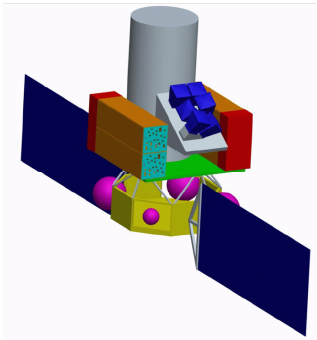
# The X-ray Telescope eROSITA

**eROSITA:**
german-russian telescope
launch: Sept 2013
L2 orbit



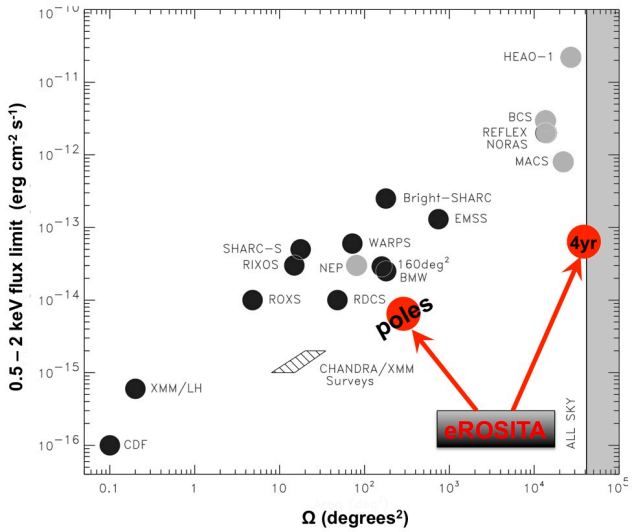
| Basic parameter of the eRosita instruments | |
|---|---|
| number of mirror systems | 7 |
| number of nested mirror shells | 54 |
| HEW (Half energy Width) | < 15" (on axis) to ~30" (survey) at 1 keV |
| energy range | 0.5 - 10 KeV |
| diameter of 1 mirror system | 358 mm |
| focal length | 1600 mm |
| material of mirror shells | nickel |
| mirror coating | gold |
| detector principle | framestore pn-CCD |
| size | 28.8 x 28.8 mm (61 arcmin diameter) |
| Pixel size | 75 x 75 µm |
| exposure time per frame | 50 msec |
| energy resolution | 138 eV at 6 keV |
| total weight of instrument | 735 kg |
| Size (diameter / length) | 1.3 m / 2.6 m |
| power consumption | 352 Watt |
| mission lifetime | > 7 years |

# eROSITA Cluster Survey



~ $10^5$ X-ray clusters of galaxies

- full sky (27,000 deg$^2$)
- $cts_{min}$ = 50 photons
- Band 0.5-2 keV




PARAMETERS: **cosmological + fnl + scaling-relation**

QUANTITIES: cluster abundances + angular clustering

OBSERVABLE: **raw photon counts**

Photometric/Spectroscopic follow-up for redshifts... ?
(Spiders :-) , 4MOST, DES, ...?)

# Our analysis with eROSITA: Fisher Matrix Forecast

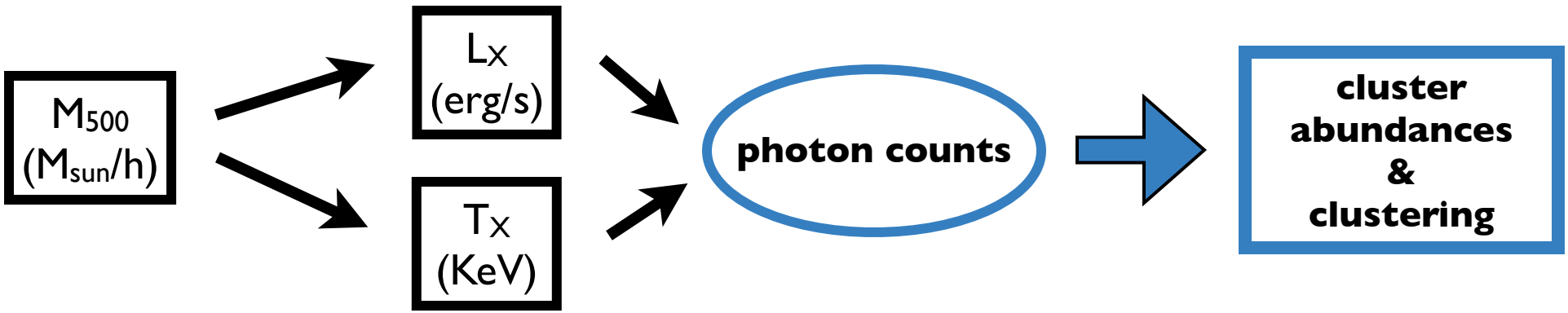
| Cosmological Parameter | Description | Fiducial Value | Current error [a] | Reference |
|---|---|---|---|---|
| $f_{\rm NL}^{\rm local}$ | **Non-linearity Parameter (Local)** | 0 | $-9 \leqslant f_{\rm NL}^{\rm local} \leqslant +111$ | Komatsu et al. (2009) |
| $\sigma_8$ | **Normalization of $P(k)$** | 0.817 | $\pm 0.026$ | Komatsu et al. (2009) |
| $\Omega_{\rm m}$ | **Dark Matter Fraction** | 0.279 | $\pm 0.0073$ | Komatsu et al. (2009) |
| $n_s$ | **Spectral index** | 0.96 | $\pm 0.013$ | Komatsu et al. (2009) |
| $h$ | **Hubble Constant** | 0.701 | $\pm 0.013$ | Komatsu et al. (2009) |
| $\Omega_{\rm b}$ | **Baryon Fraction** | 0.0462 | $\pm 0.0015$ | Komatsu et al. (2009) |
| $\Omega_\Lambda$ | Dark Energy Fraction | 0.721 | $\pm 0.015$ | Komatsu et al. (2009) |
| $w$ | Equation-of-State Parameter (constant) | -1 | $-0.14 < 1 + w < 0.12$ | Komatsu et al. (2009) |
| **X-ray Cluster Parameter** | **Description** | **Fiducial Value** | **Current Error** | **Reference** |
| $\alpha_{\rm LM}$ | **LM relation: Slope** | 1.61 | $\pm 0.14$ | Vikhlinin et al. (2009a) |
| $\gamma_{\rm LM}$ | **LM relation: $z$-dependent Factor** | 1.85 | $\pm 0.42$ | Vikhlinin et al. (2009a) |
| $\beta_{\rm LM}$ | **LM relation: Normalization** | 101.483 | $\pm 0.085$ | Vikhlinin et al. (2009a) |
| $\sigma_{\rm LM}$ | **LM relation: Logarithmic Scatter** | 0.396 | $\pm 0.039$ | Vikhlinin et al. (2009a) |
| | TM relation: Slope | 0.65 | $\pm 0.03$ | Vikhlinin et al. (2009a) |
| $\beta_{\rm TM}$ | TM relation: Normalization | $3.02 \times 10^{14} M_\odot h^{-1}$ | $\pm 0.11 \times 10^{14}$ | Vikhlinin et al. (2009a) |
| $\sigma_{\rm TM}$ | TM relation: Logarithmic Scatter | 0.119 | 0.03[b] | Kravtsov, Vikhlinin & Nagai (2006) |
| $\rho_{\rm LT}$ | LT correlation coefficient | 0 | - | - |
| $Z_{\rm ICM}$ | Intracluster metallicity | $0.3 Z_\odot$ | - | Anders & Grevesse (1989) |
| $N_{\rm H}$ | Hydrogen column density along los | $3 \times 10^{20}$ atom/cm$^2$ | - | Kalberla et al. (2005) |
| **Survey Parameter** | **Description** | **Fiducial Value** | **-** | **Reference** |
| | X-ray Energy Band | 0.5-2 keV | - | - |
| $\eta_{\rm min}$ | Minimum raw photon count | 50 | - | - |
| $M_{\rm min}$ | Minimum considered mass ($M_{500}$) | $5 \times 10^{13} M_\odot h^{-1}$ | - | - |
| $f_{\rm sky}$ | Sky coverage | $0.658 \Rightarrow 27,145$ deg$^2$ [c] | - | Predehl et al. (2010) |
| $T_{\rm exp}$ | Exposure Time | $1.6 \times 10^3$s (all-sky survey) | - | - |

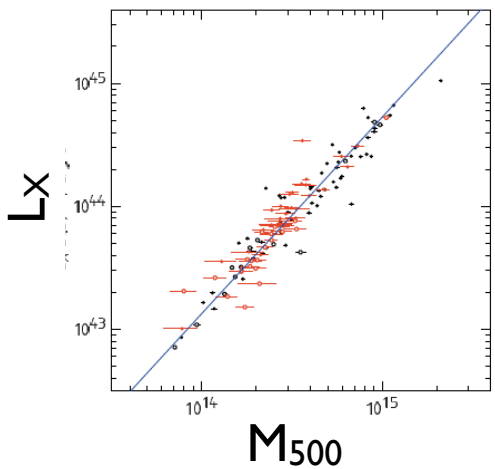
[a] WMAP5+BAO+SN, for the Cosmology sector (68.3 per cent credibility interval (CI), with the exception of $f_{\rm NL}^{\rm local}$ for which the 95.4 CI per cent is indicated)

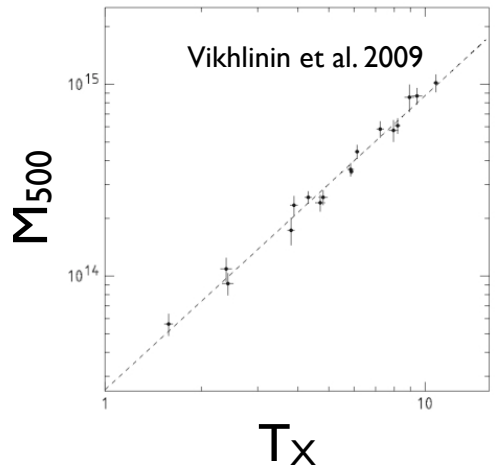
[b] from hydrodynamical simulations

[c] *all-sky* survey excising $\pm 20$ deg around the galactic plane

# From the Mass to the X-ray observable



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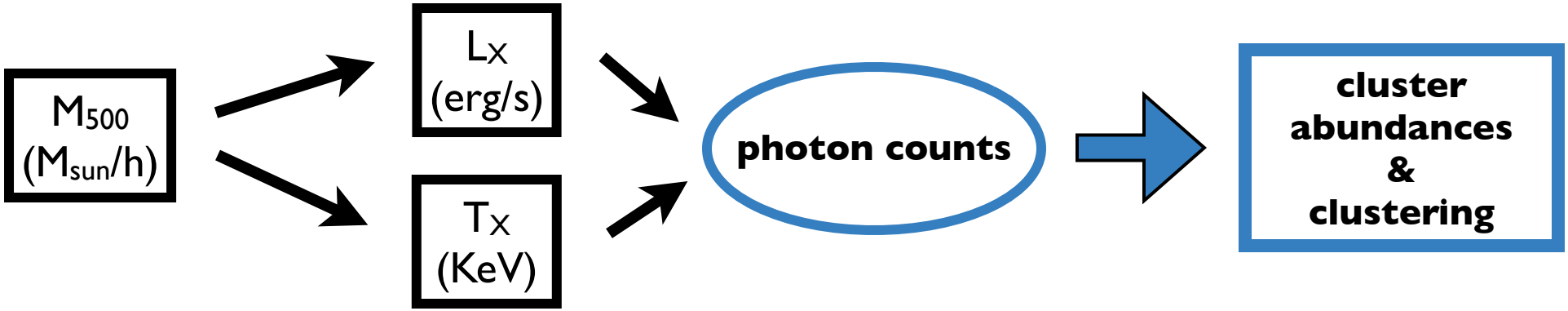
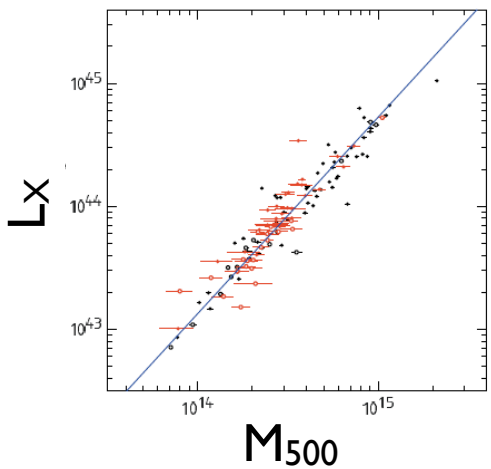
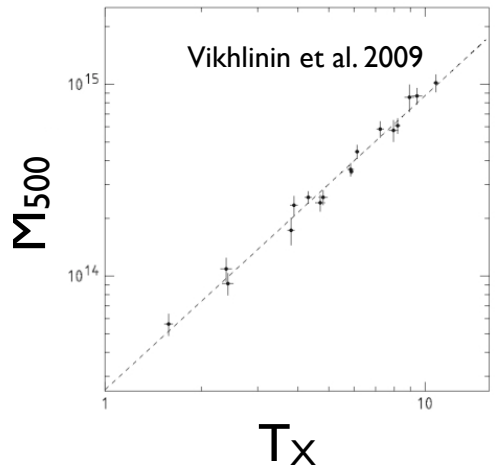
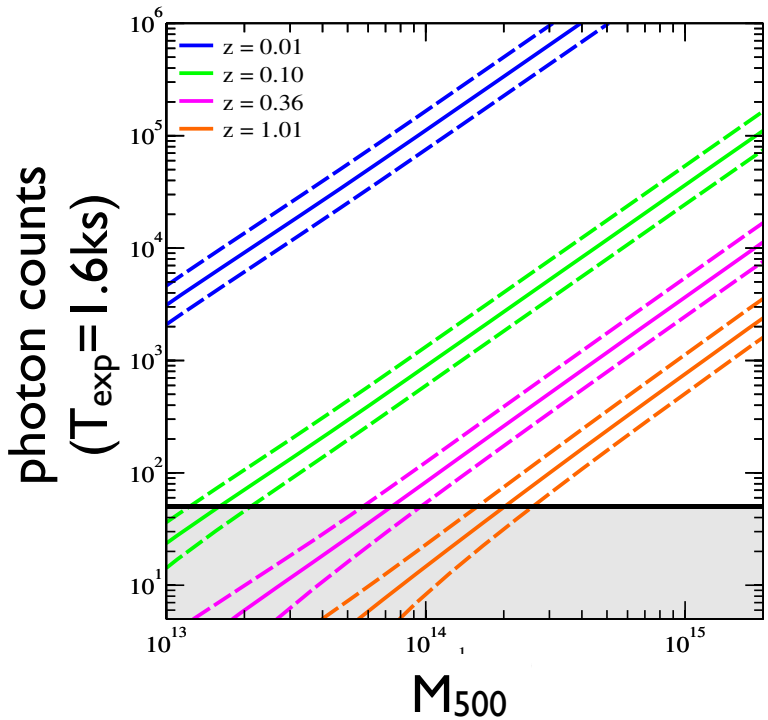
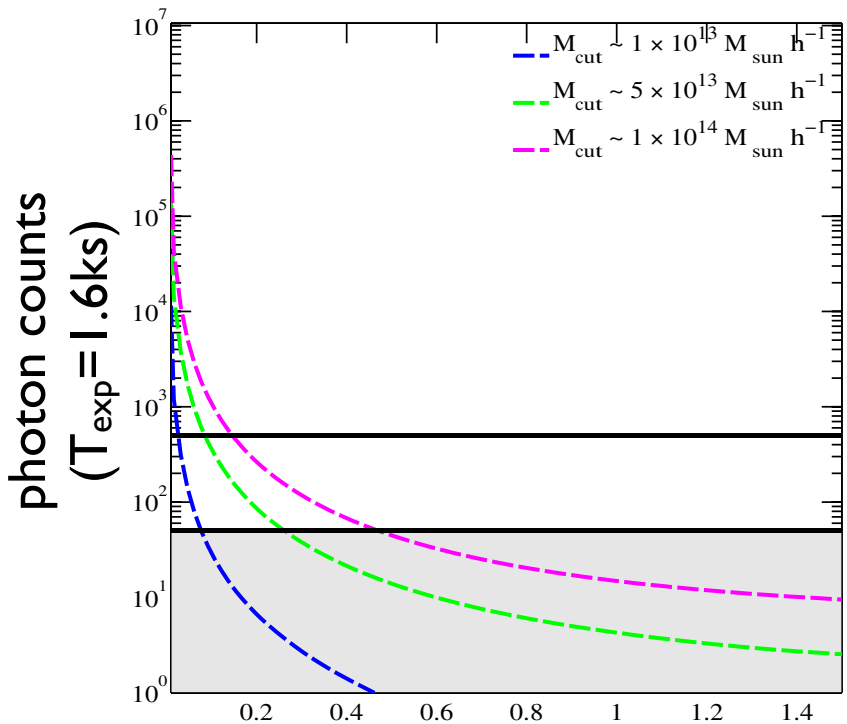


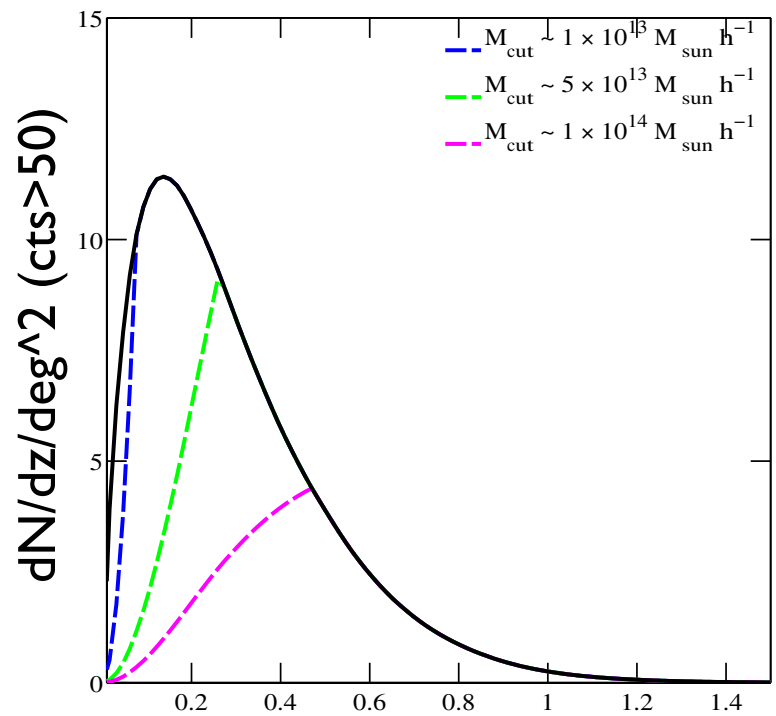



# eROSITA: selections and numbers




all sky

| | $N_{\rm clusters}$ ($\eta_{\rm min} = 50, T_{\rm exp} = 1.6$ ks) | $z_{\rm median}$ |
|---|---|---|
| all objects | $1.37 \times 10^5$ | 0.25 |
| $M \gtrsim 1 \times 10^{13}\ (h^{-1} M_\odot)$ | $1.31 \times 10^5$ | 0.27 |
| $M \gtrsim 5 \times 10^{13}\ (h^{-1} M_\odot)$ | $9.32 \times 10^4$ | 0.35 |
| $M \gtrsim 1 \times 10^{14}\ (h^{-1} M_\odot)$ | $5.57 \times 10^4$ | 0.46 |

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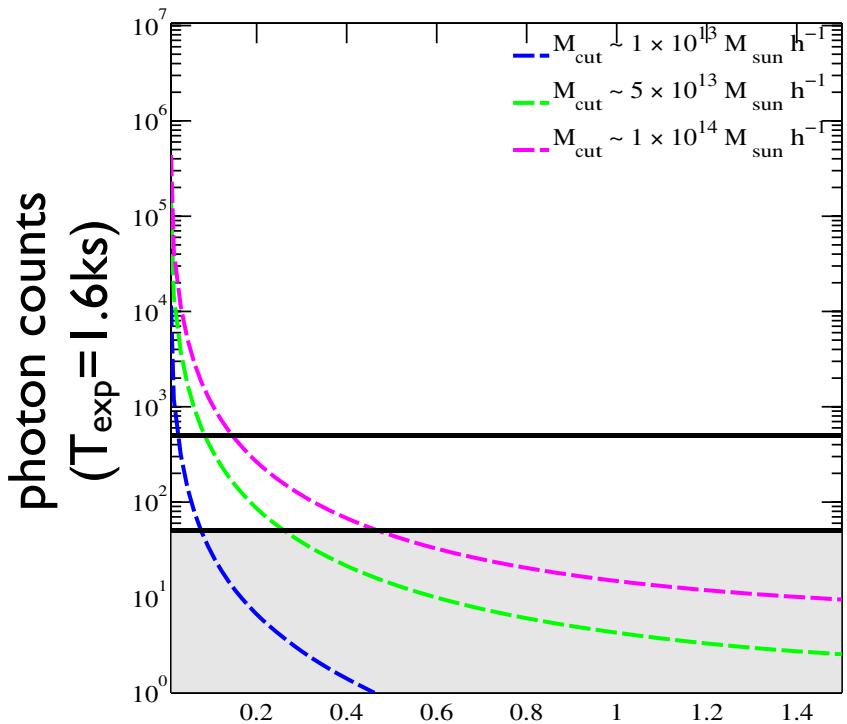


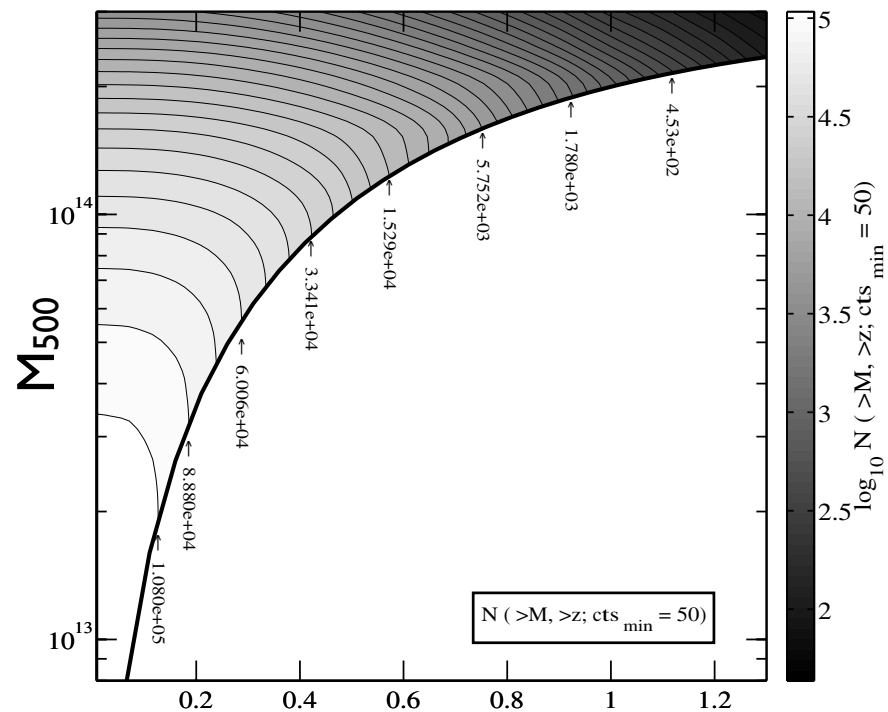


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# Effects of local primordial non-Gaussianity

## I) Dark Matter Halo Mass Function

⇨ Abundances of clusters

## II) Dark Matter Halo Bias

⇨ Spatial clustering of clusters

# Our models of reference

Mass Function: **Tinker et al. 2008**

$$\left(\frac{dn}{dM}\right)_{\rm NG} = \left(\frac{dn}{dM}\right)_{\rm T,M_{500}} R_{\rm NG}(M, z, f_{\rm NL}).$$

**LoVerde et al. 2008**

Halo Bias:

$$b(k, M, z) = (1 + b_{\rm PBS}) + f_{\rm NL}^{\rm local} b_{\rm PBS} \frac{\Gamma}{\alpha(k, z)}.$$

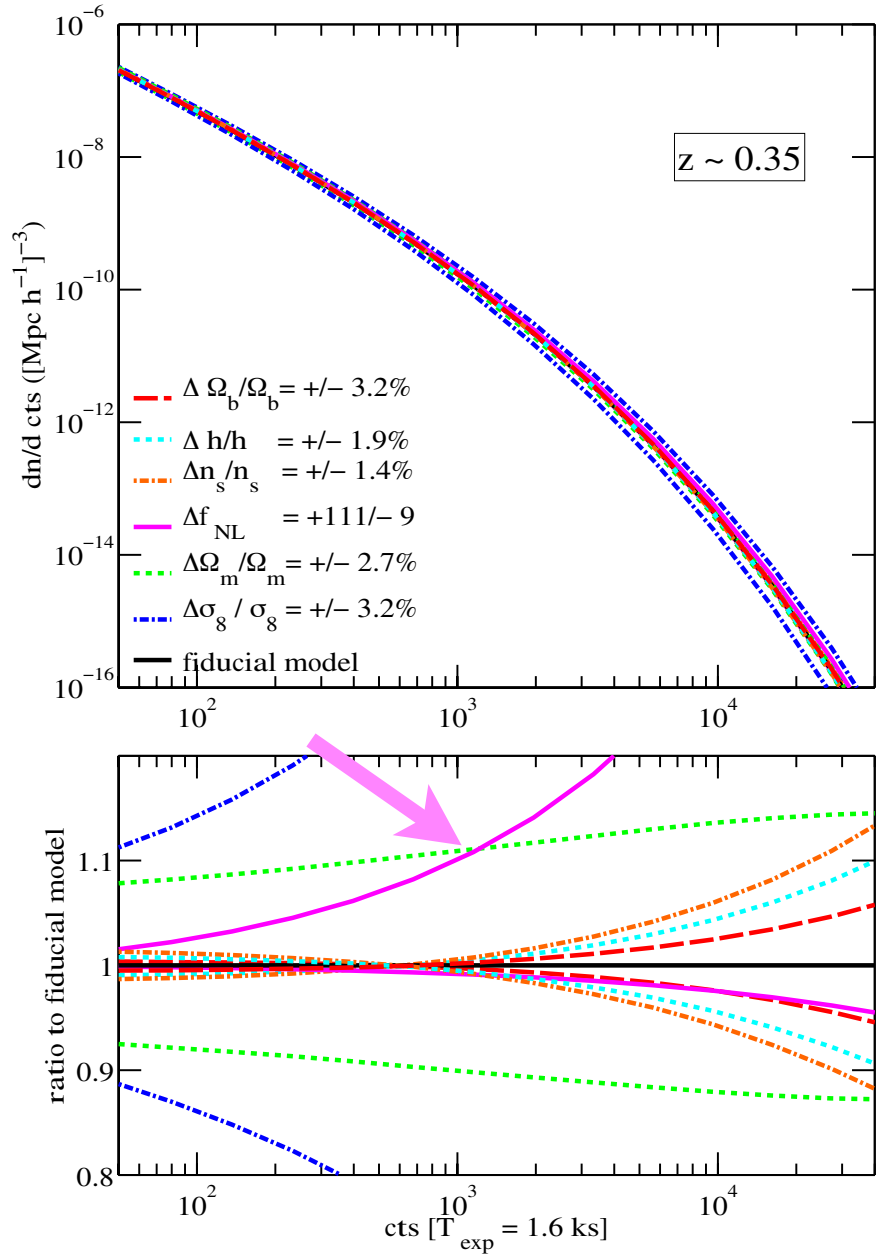
**(Desjacques et al. 2009 v3, Giannantonio & Porciani 2010)**

# Cluster abundances

larger values of $f_{NL}$

↓

higher abundances of most massive haloes

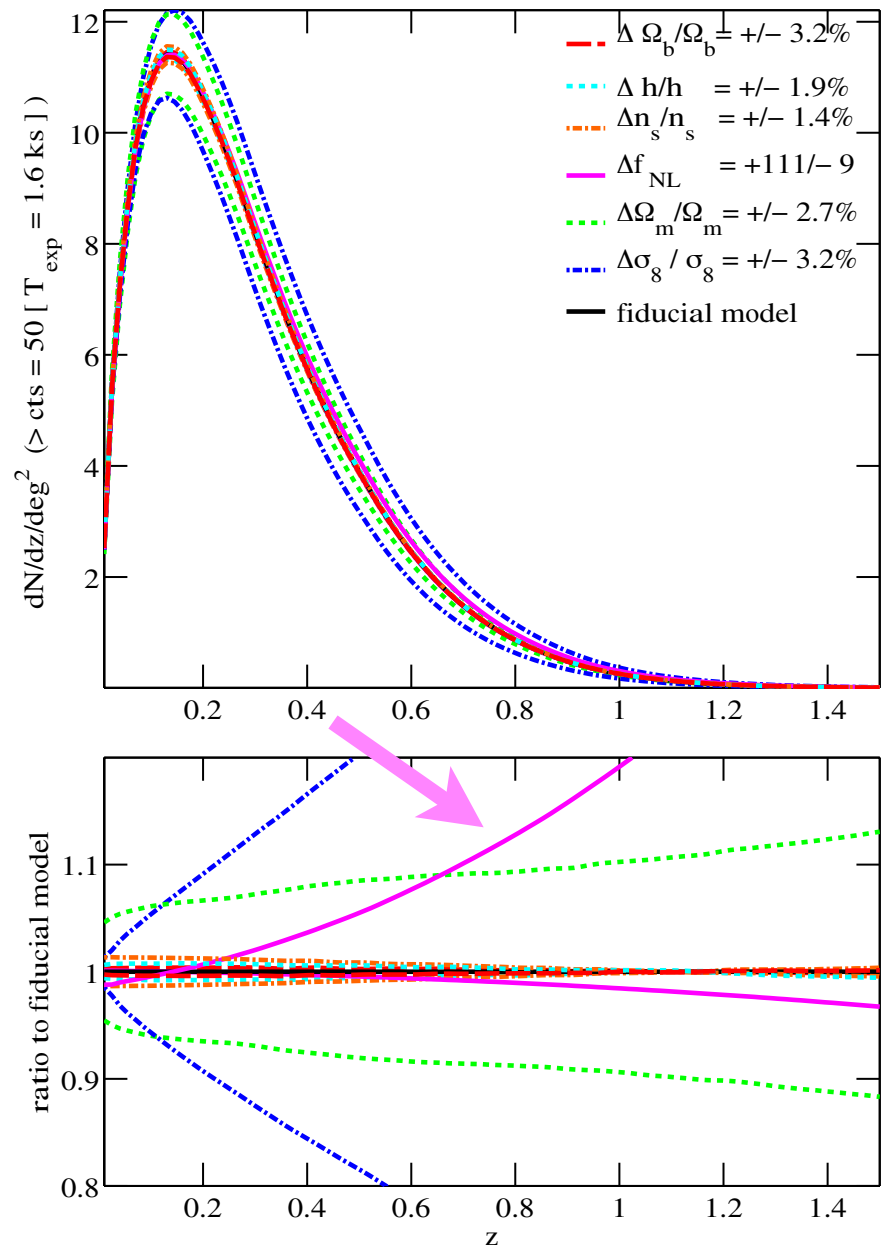


# Cluster abundances

higher redshifts

↓

higher relative effect of primordial NG

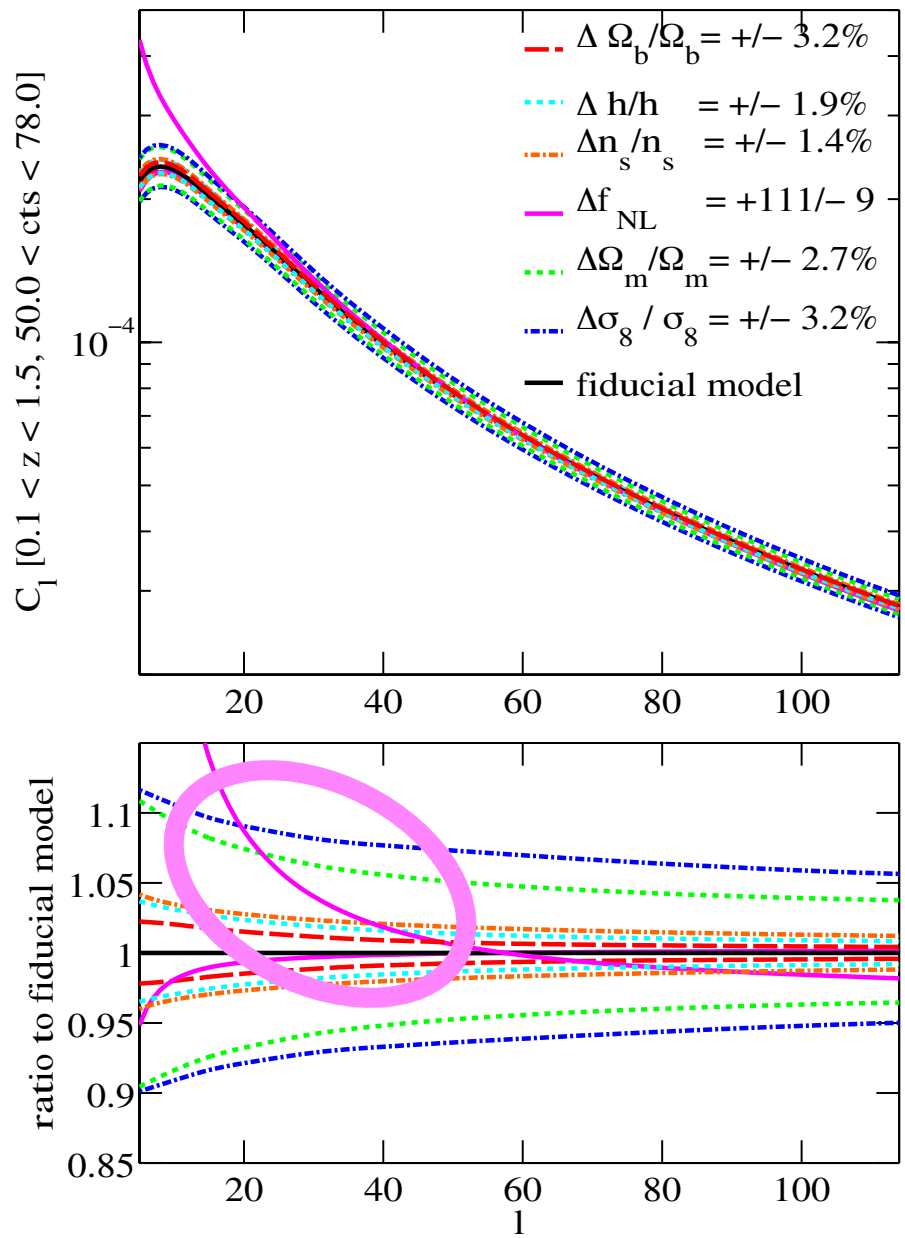


# Angular Clustering

$f_{NL}$ ~=0

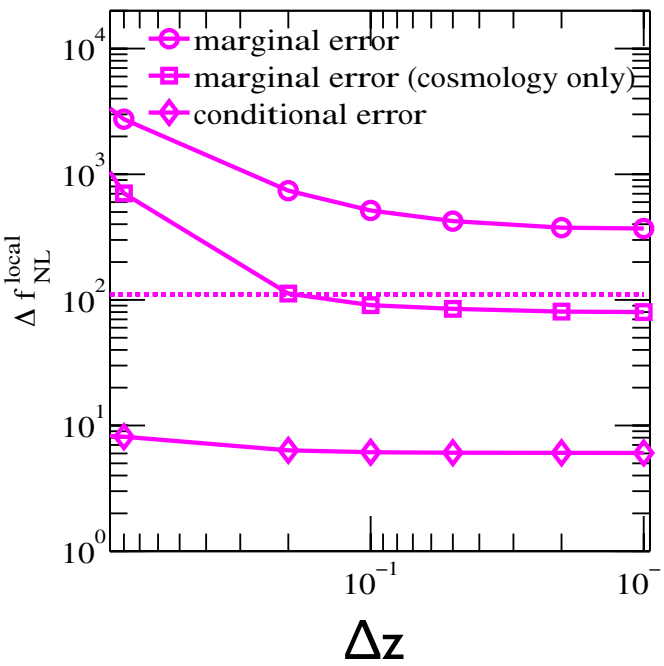
↓

scale-dependent signature!!!

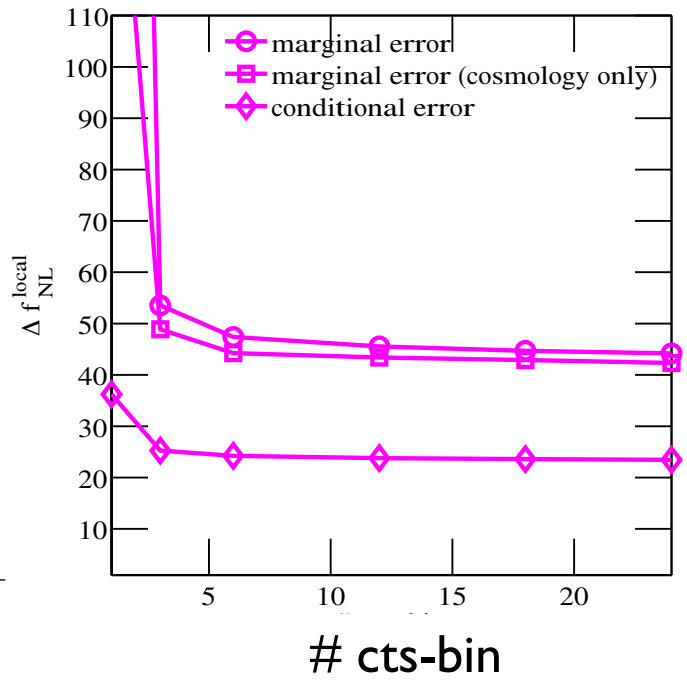


# Optimization

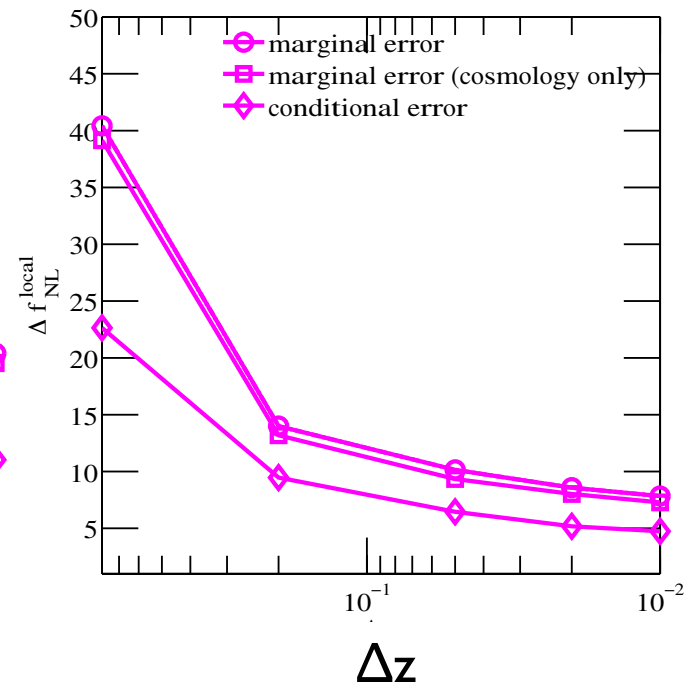
**Cluster Counts**
Bins in raw counts + bins in redshift




**Angular Clustering**
Bins in raw counts




**Tomography**
Bins in raw counts + redshift



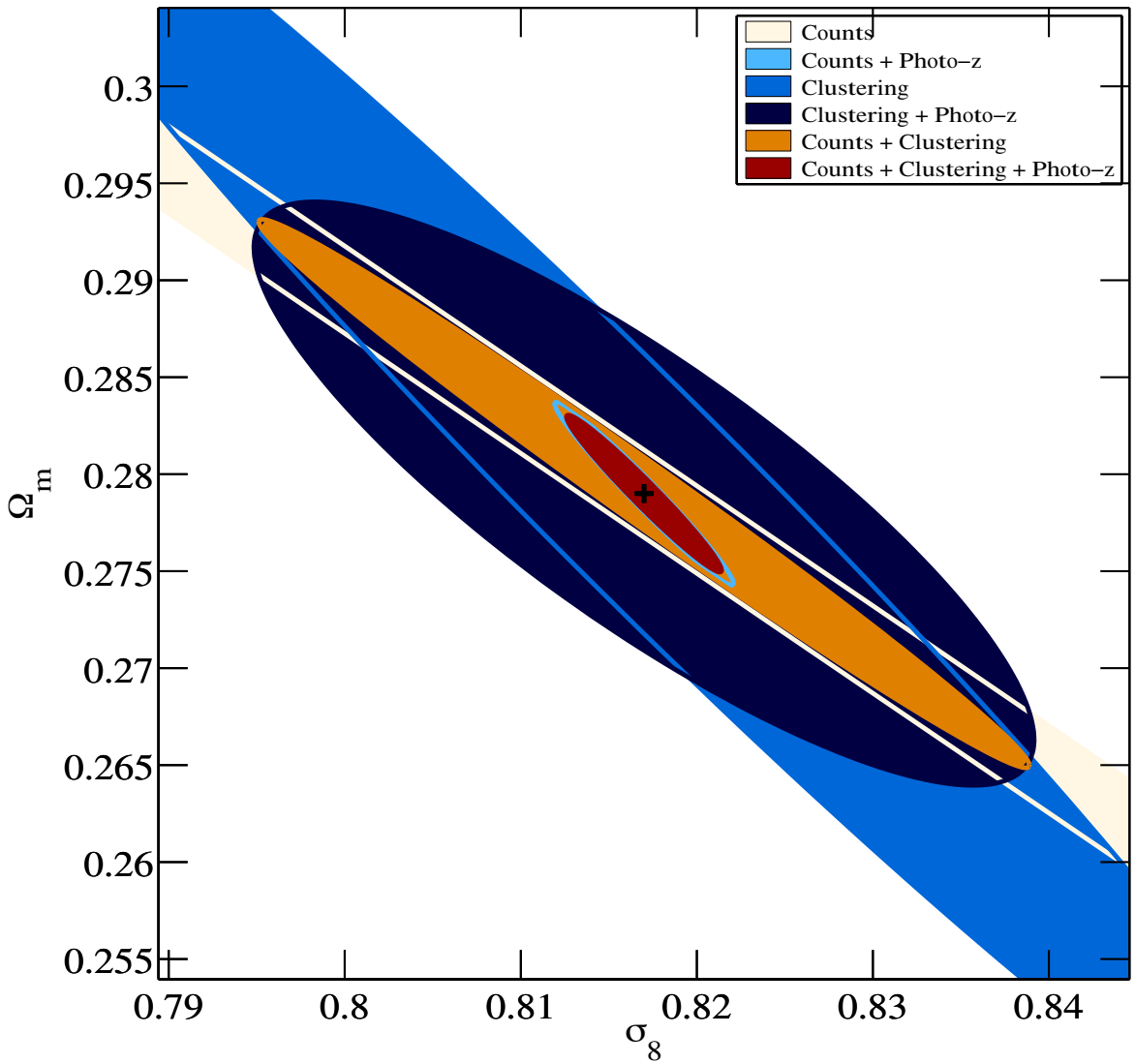

Without redshift, no chance!

This due to degeneracies:

$\Delta f_{NL}^{conditional} \sim 9$; $\Delta \sigma_8^{conditional} \sim 10^{-4}$

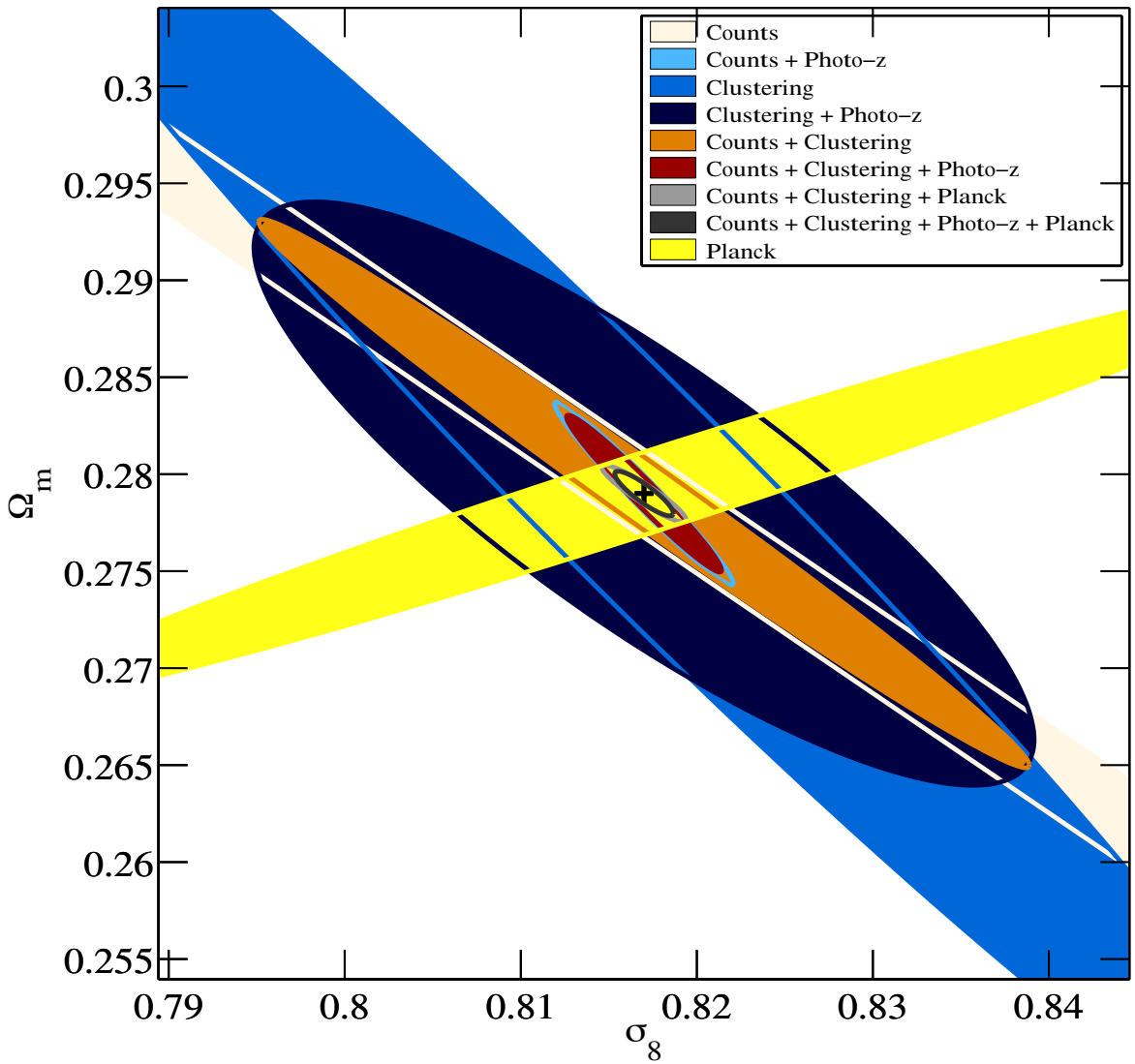
$\Delta bin \sim \Delta z\ (1+z)$

# Results with eROSITA: flat ΛCDM



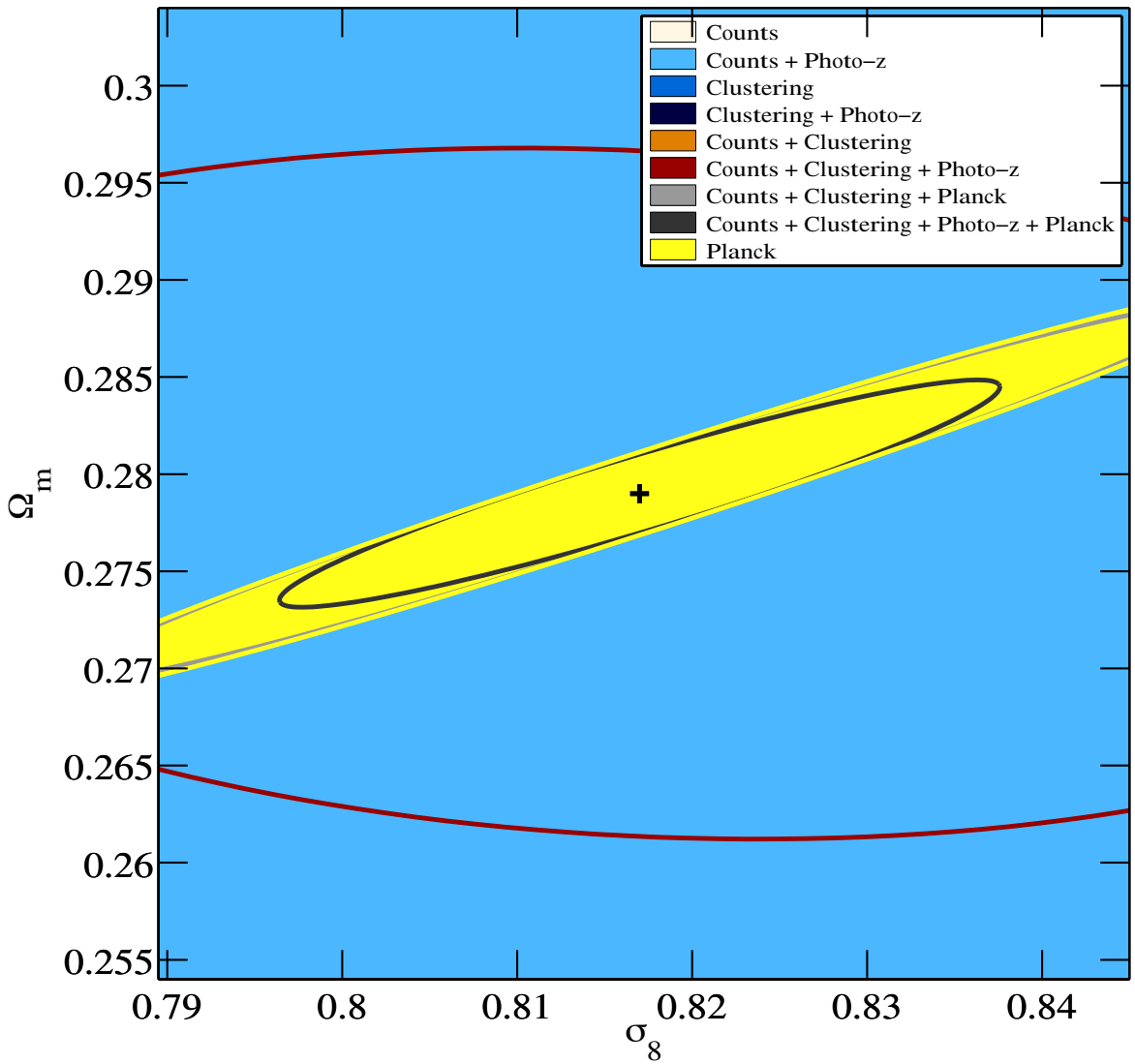

$\Omega_m$, $\sigma_8$, $n_s$, h, $\Omega_b$

# Results with eROSITA: flat ΛCDM




$\Omega_m$, $\sigma_8$, $n_s$, h, $\Omega_b$

# Results with eROSITA: self-calibration




$\Omega_m, \sigma_8, n_s, h, \Omega_b$

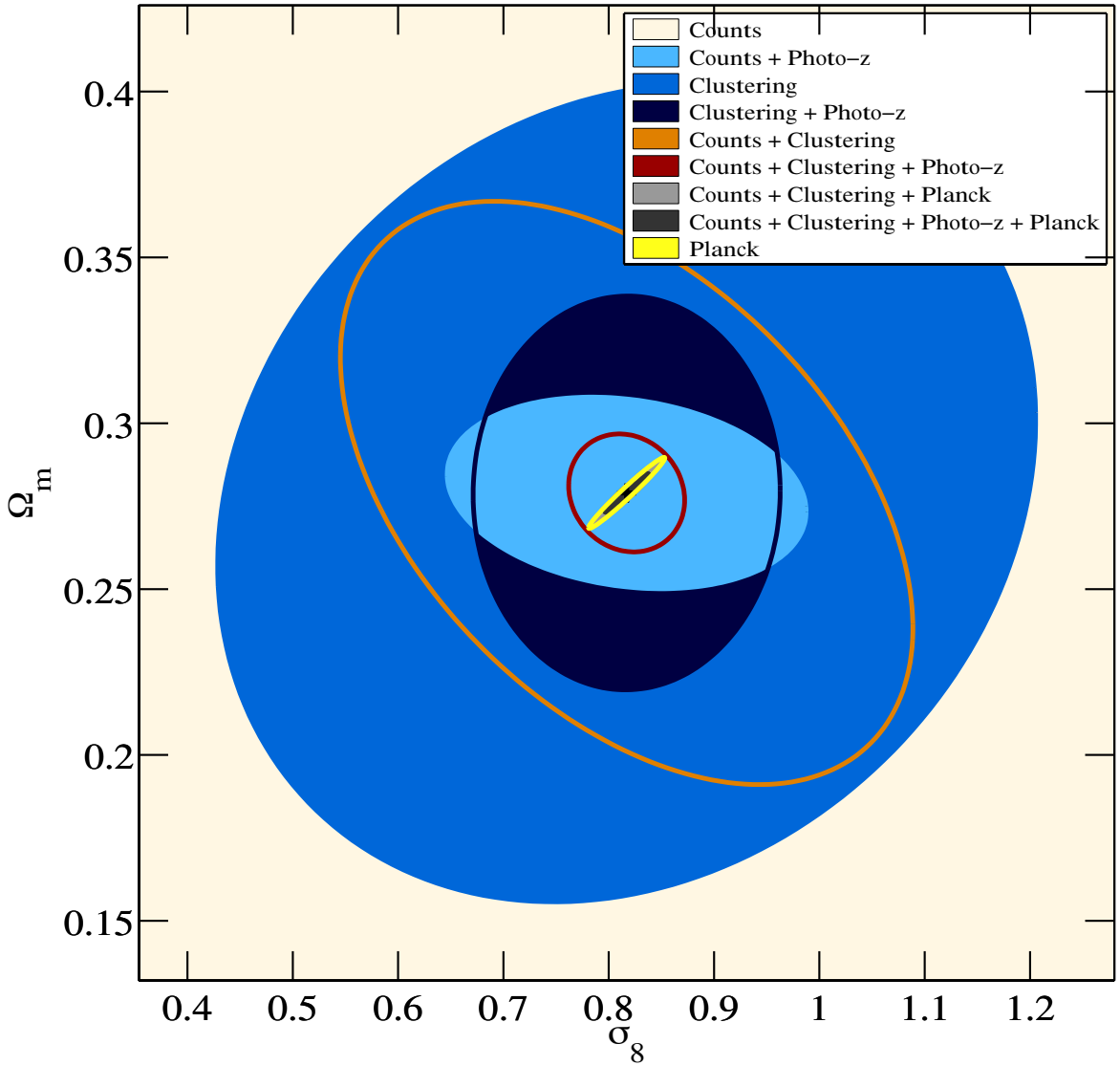
+

$f_{NL}$

+

$\alpha_{LM}, \beta_{LM}, \gamma_{LM}, \sigma_{LM}$

# Results with eROSITA: self-calibration




$\Omega_m, \sigma_8, n_s, h, \Omega_b$

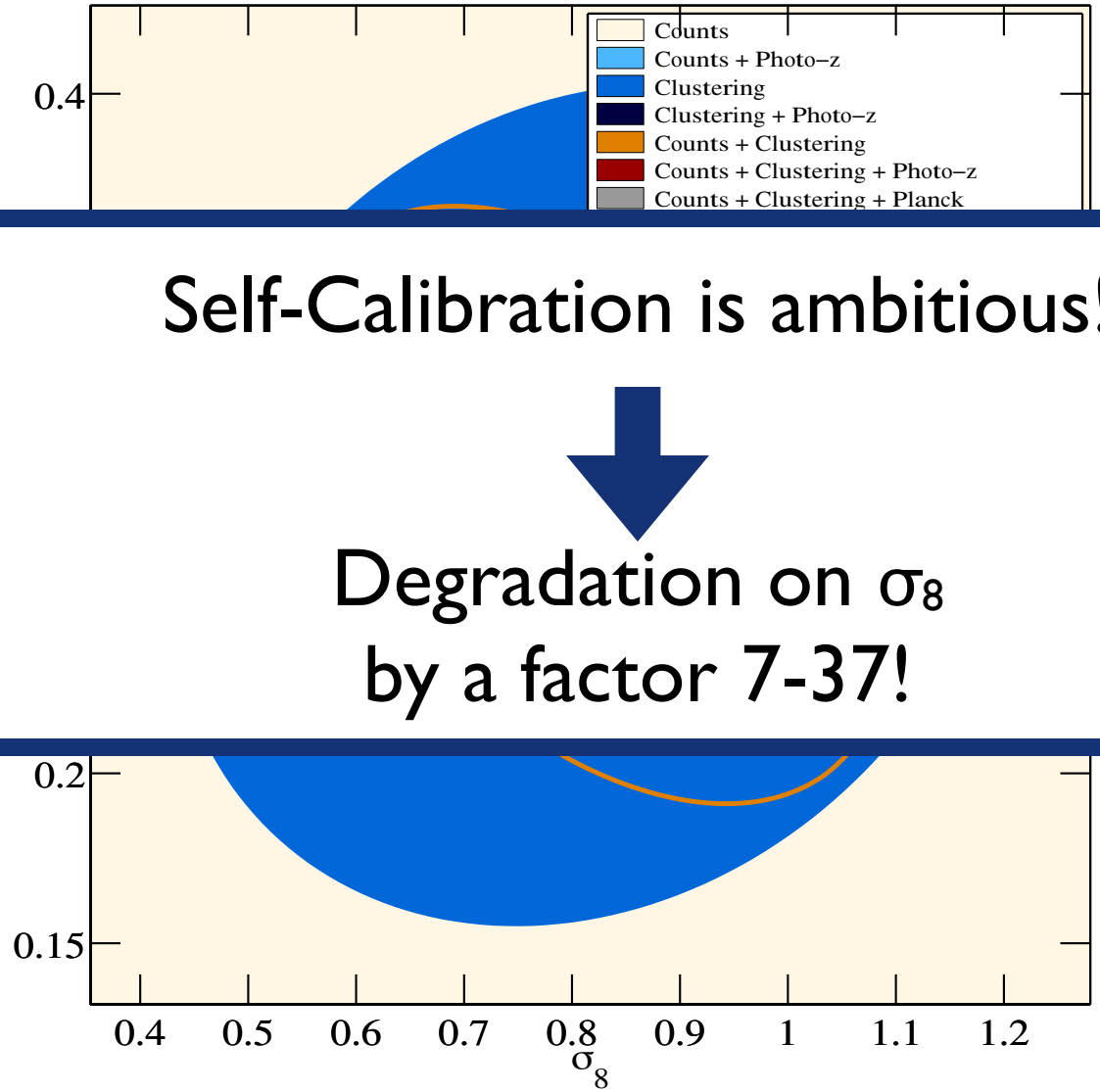
+

$f_{NL}$

+

$\alpha_{LM}, \beta_{LM}, \gamma_{LM}, \sigma_{LM}$

# Results with eROSITA: self-calibration




Self-Calibration is ambitious!

Degradation on $\sigma_8$ by a factor 7-37!

$n_s$, h, $\Omega_b$

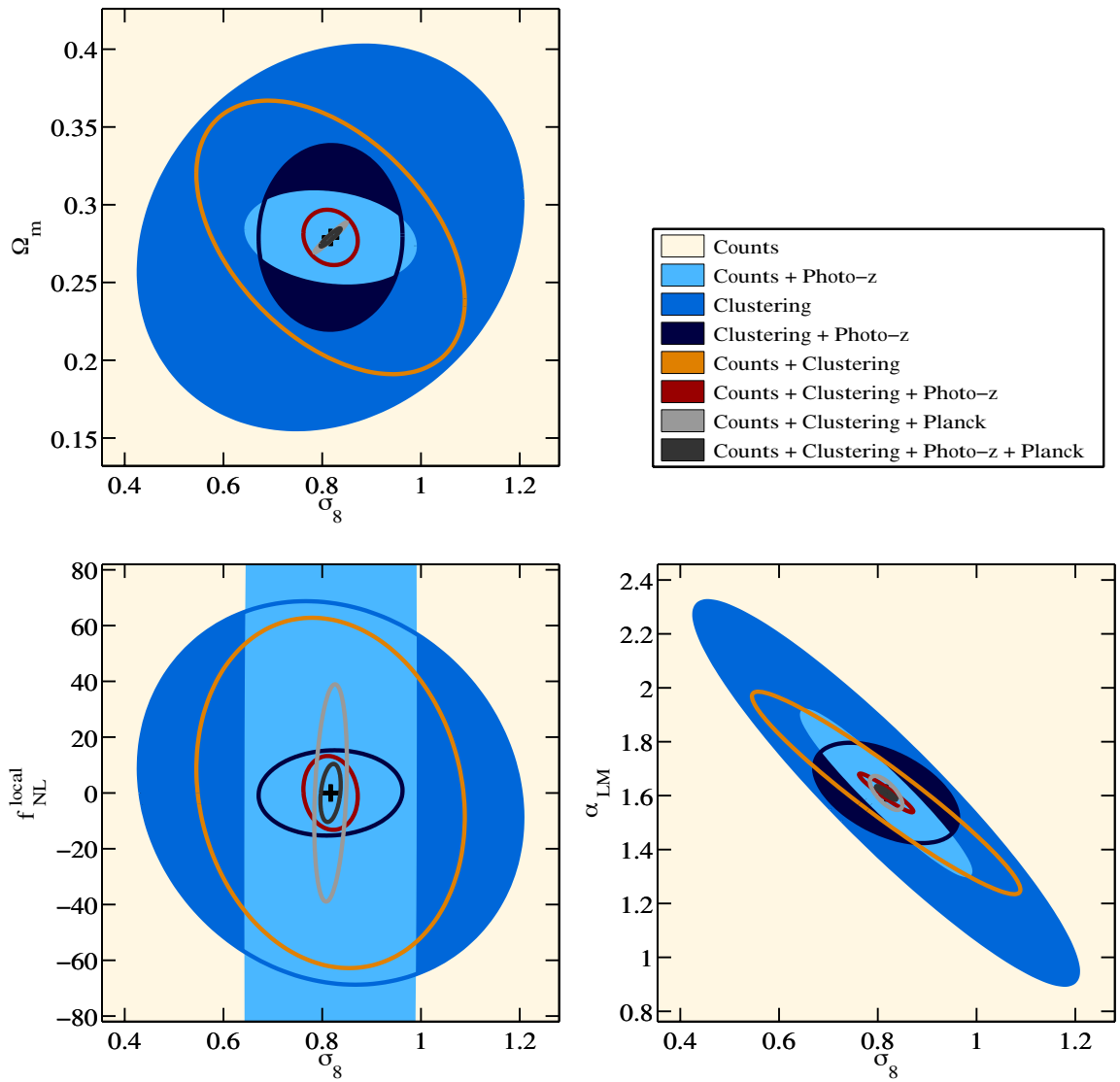
+

$f_{NL}$

+

$\alpha_{LM}$, $\beta_{LM}$, $\gamma_{LM}$, $\sigma_{LM}$

# Results with eROSITA: self-calibration

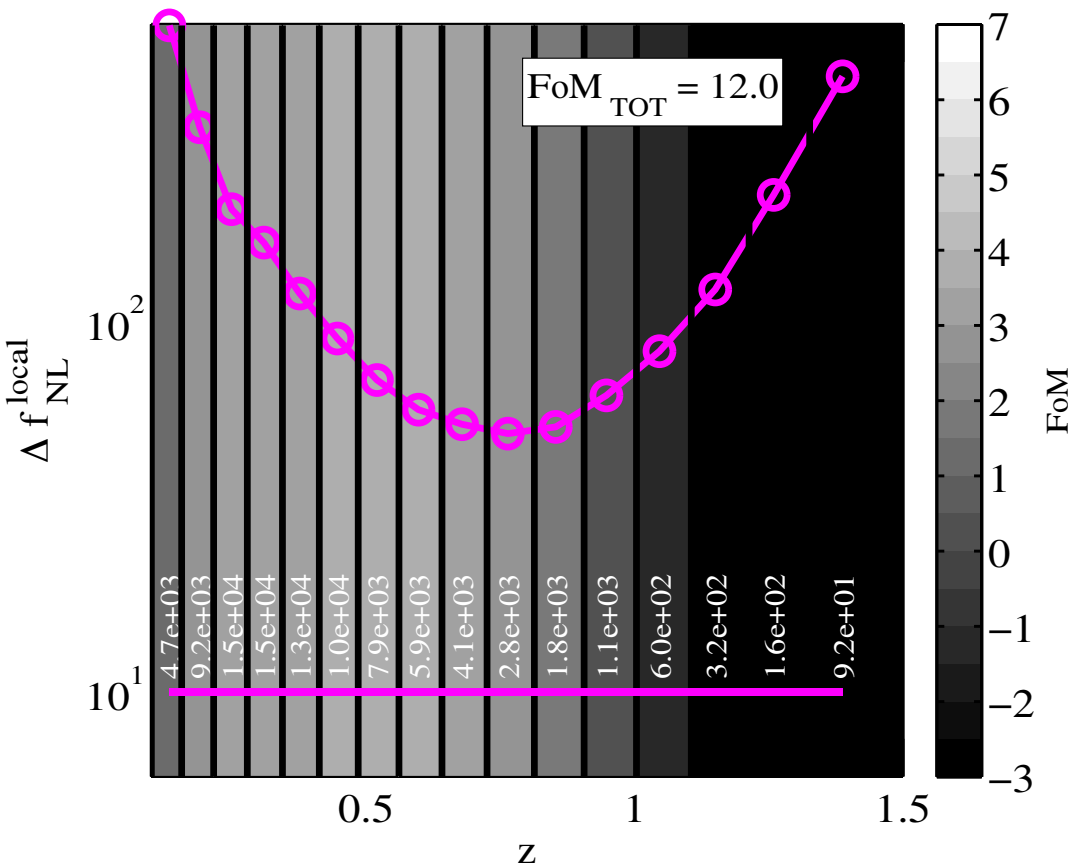


# Results with eROSITA: self-calibration

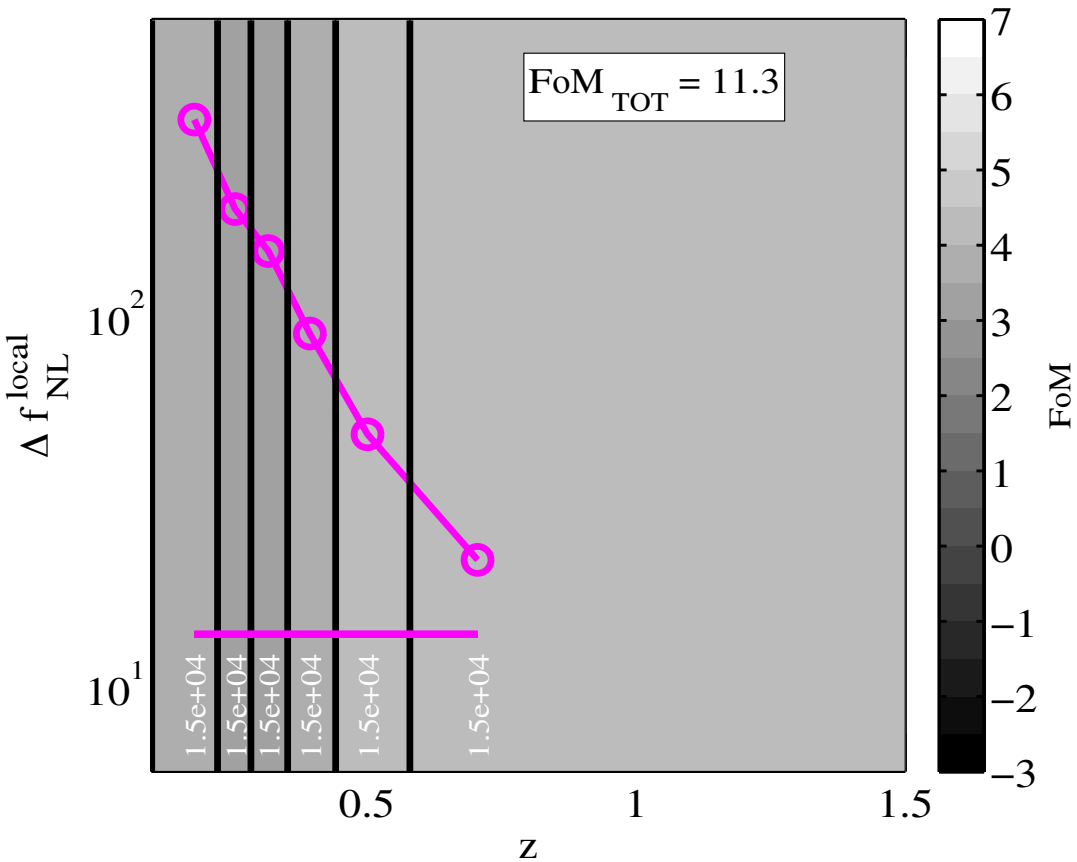
| *eROSITA* data | FoM | $\Delta f_{\rm NL}^{\rm local}$ | $\Delta\sigma_8$ | $\Delta\Omega_{\rm m}$ | $\Delta n_s$ |
|---|---|---|---|---|---|
| Counts | 1.0 | $\sim 9\times10^3$ | $\sim 1.6$ | $\sim .5$ | $\sim 4$ |
| Counts + Priors | 4.6 | $\sim 8\times10^3$ | $\sim 1.5$ | $\sim .4$ | $\sim 2$ |
| Counts + Photo-$z$ | 10.7 | 423 | .113 | .0191 | .559 |
| Counts + Photo-$z$ + Priors | 12.8 | 360 | .100 | .0188 | .205 |
| Angular clustering | 7.1 | 46 | .257 | .0817 | .845 |
| Angular clustering + Priors | 9.1 | 42 | .226 | .0693 | .256 |
| Angular clustering + Photo-$z$ | 12.0 | 10.1 | .097 | .0393 | .264 |
| Angular clustering + Photo-$z$ + Priors | 13.2 | 9.8 | .095 | .0207 | .076 |
| Counts + Angular clustering | 10.6 | 42 | .180 | .0582 | .530 |
| Counts + Angular clustering + Priors | 12.5 | 37 | .169 | .0531 | .154 |
| Counts + Angular clustering + Photo-$z$ | 16.3 | 8.8 | .036 | .0118 | .088 |
| Counts + Angular clustering + Photo-$z$ + Priors | 17.2 | 8.2 | .036 | .0111 | .033 |
| Counts + Angular clustering + LM fixed | - | 36 | .016 | .0099 | .172 |
| Counts + Angular clustering + Photo-$z$ + LM fixed | - | 8.4 | .003 | .0029 | .055 |
| Counts + Angular clustering + Planck | 19.7 | 26 | .022 | .0065 | .004 |
| Counts + Angular clustering + Photo-$z$ + Planck | 22.1 | 6.9 | .014 | .0039 | .003 |
| Current Errors[a] | - | [-10,+74] | .024 | .0061 | .012 |
| Planck Errors[b] | - | - | .024 | .0071 | .004 |

+ h, $\Omega_b$ and X-ray scaling relation parameters ...

# Where does the information come from?

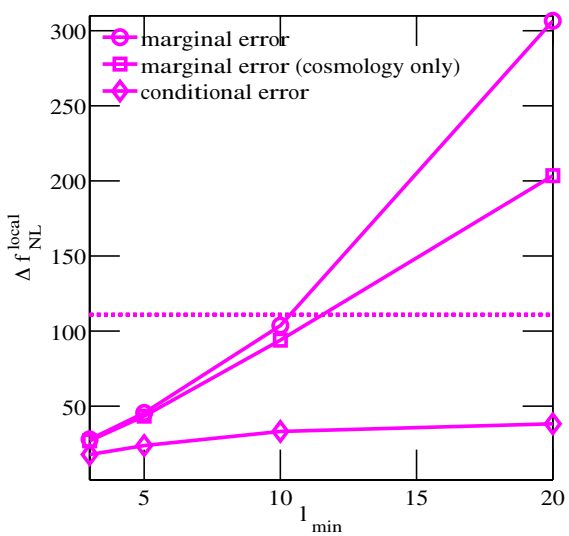


# Where does the information come from?



# Playing in the parameter-space

| Surveys | area ($deg^2$) | $T_{exp}$(ks) | $N_{objects}$ | $\Delta f_{NL}^{local}$ | $FoM^{Cosmo}$ | $FoM^{ICM}$ |
|---|---|---|---|---|---|---|
| *eROSITA* | 27‘000 | 1.6 | $9.32 \times 10^4$ | 8.8 | 8.0 | 5.3 |
| Deeper *eROSITA* | 27‘000 | 3.0 | $1.61 \times 10^5$ | 6.5 | 8.6 | 5.6 |
| Focussed *eROSITA* | 6‘000 | 7.5 | $6.85 \times 10^4$ | 21.1 | 6.4 | 4.3 |
| 1/2 *eROSITA* | 13‘500 | 1.6 | $4.66 \times 10^4$ | 18.9 | 6.5 | 4.6 |
| (1/2 + 1/2) *eROSITA* | 27‘000 | 1.6 | $9.32 \times 10^4$ | 13.4 | 7.3 | 5.1 |
| $z \leqslant 1$ *eROSITA* | 27‘000 | 1.6 | $9.19 \times 10^4$ | 9.5 | 7.8 | 5.2 |
| “The magnificent 1000” | 27‘000 | 1.6 | $\sim$1000 | 41 | 2.0 | 1.1 |




The all-sky survey is the best ;-)

# Primordial non-Gaussianity beyond the Local Model

| *eROSITA* Data | $\Delta f_{\rm NL}^{\rm local}$ | $\Delta f_{\rm NL}^{\rm ortho}$ | $\Delta f_{\rm NL}^{\rm equil}$ |
|---|---|---|---|
| Counts | $9 \times 10^3$ | $4 \times 10^4$ | $2 \times 10^4$ |
| Counts + Photo-$z$ | 423 | $2 \times 10^3$ | $1 \times 10^3$ |
| Angular clustering | 46 | 461 | $1.4 \times 10^3$ |
| Angular clustering + Photo-$z$ | 10.1 | 102 | $1.3 \times 10^3$ |
| Counts + Angular clustering | 42 | 317 | $1.1 \times 10^3$ |
| Counts + Angular clustering + Photo-$z$ | 8.8 | 36 | 144 |
| Counts + Angular clustering + Planck | 26 | 168 | 740 |
| Counts + Angular clustering + Photo-$z$ + Planck | 6.9 | 19 | 115 |
| WMAP7, 95 per cent C.I. | [-10, +74] | [-410, +6] | [-214, +266] |
| Komatsu et al. (2011) | | | |

$f_{NL}^{local}$ has the biggest effects, thus the best constraints

bias $\propto k^{-2}$

bias $\propto k^{-1}$

bias $\propto$ const

# .... more details on Pillepich et al. 2011, submitted

## Concluding...

- With eROSITA, good constraints on the primordial non-Gaussianity will be obtained, also with self-calibration and without priors.

- The information comes in major part from the large-scale scale-dependent effect of $f_{NL}^{local}$ on the clustering of collapsed objects

- **Knowledge of individual redshifts is fundamental to break the degeneracies among parameters, both with counts and clustering**

- eROSITA will contribute to further shrink Planck constraints on ΛCDM parameters

- Primordial non-Gaussianity does not sensibly degrade the best cosmological constraints from abundance and clustering of clusters! BUT the Luminosity-Mass observable parameters do!

## Thanks!