The X-ray cluster survey with eROSITA: predictions for cosmology, cluster physics, and primordial non-Gaussianity

Annalisa Pillepich
SNF fellow at UCSC

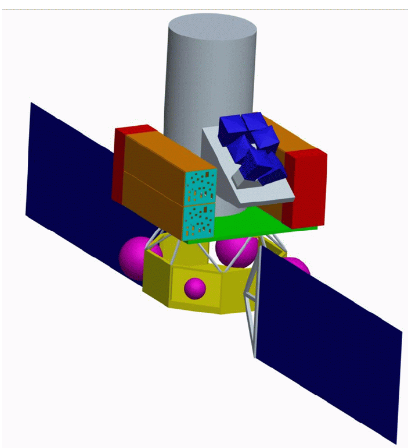
from A. Pillepich, C. Porciani and T. Reiprich 2011, submitted to MNRAS

The Idea

eROSITA → ~ 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_{NL}^{local}	**Non-linearity Parameter (Local)**	0	$-9 \leqslant f_{NL}^{local} \leqslant +111$	Komatsu et al. (2009)
σ_8	**Normalization of $P(k)$**	0.817	± 0.026	Komatsu et al. (2009)
Ω_m	**Dark Matter Fraction**	0.279	± 0.0073	Komatsu et al. (2009)
n_s	**Spectral index**	0.96	± 0.013	Komatsu et al. (2009)
h	**Hubble Constant**	0.701	± 0.013	Komatsu et al. (2009)
Ω_b	**Baryon Fraction**	0.0462	± 0.0015	Komatsu et al. (2009)
Ω_Λ	Dark Energy Fraction	0.721	± 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
α_{LM}	**LM relation: Slope**	1.61	± 0.14	Vikhlinin et al. (2009a)
γ_{LM}	**LM relation: z-dependent Factor**	1.85	± 0.42	Vikhlinin et al. (2009a)
β_{LM}	**LM relation: Normalization**	101.483	± 0.085	Vikhlinin et al. (2009a)
σ_{LM}	**LM relation: Logarithmic Scatter**	0.396	± 0.039	Vikhlinin et al. (2009a)
α_{TM}	TM relation: Slope	0.65	± 0.03	Vikhlinin et al. (2009a)
β_{TM}	TM relation: Normalization	$3.02 \times 10^{14} M_\odot h^{-1}$	$\pm 0.11 \times 10^{14}$	Vikhlinin et al. (2009a)
σ_{TM}	TM relation: Logarithmic Scatter	0.119	0.03[b]	Kravtsov, Vikhlinin & Nagai (2006)
ρ_{LT}	LT correlation coefficient	0	-	-
Z_{ICM}	Intracluster metallicity	$0.3 Z_\odot$	-	Anders & Grevesse (1989)
N_H	Hydrogen column density along los	3×10^{20} atom/cm^2	-	Kalberla et al. (2005)

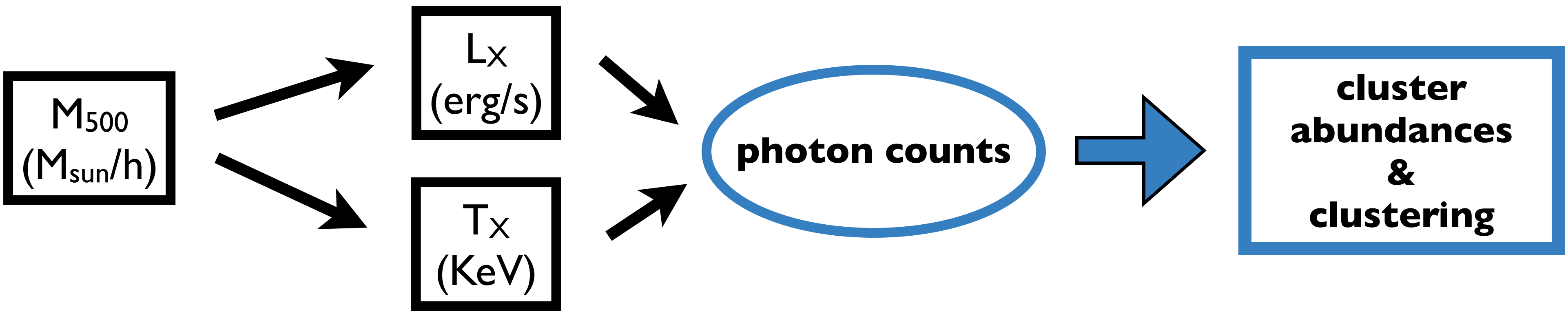
Survey Parameter	Description	Fiducial Value	-	Reference
	X-ray Energy Band	0.5-2 keV	-	-
η_{min}	Minimum raw photon count	50	-	-
M_{min}	Minimum considered mass (M_{500})	$5 \times 10^{13} M_\odot h^{-1}$	-	-
f_{sky}	Sky coverage	$0.658 \Rightarrow 27,145$ deg^2 [c]	-	Predehl et al. (2010)
T_{exp}	Exposure Time	1.6×10^3s (all-sky survey)	-	-

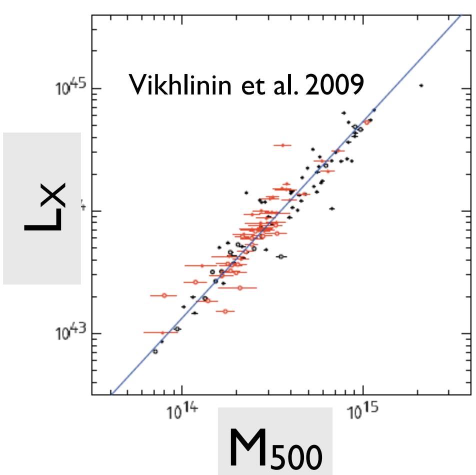
[a] WMAP5+BAO+SN, for the Cosmology sector (68.3 per cent credibility interval (CI), with the exception of f_{NL}^{local} for which the 95.4 CI per cent is indicated)

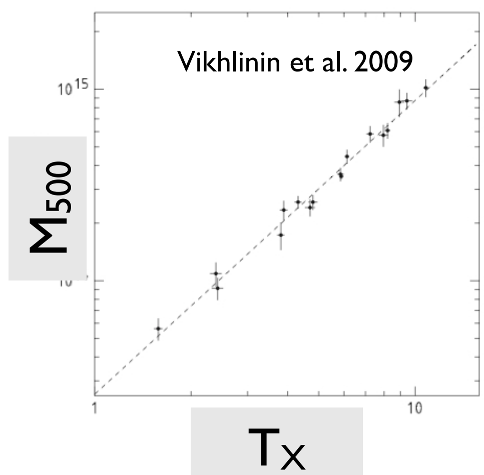
[b] from hydrodynamical simulations

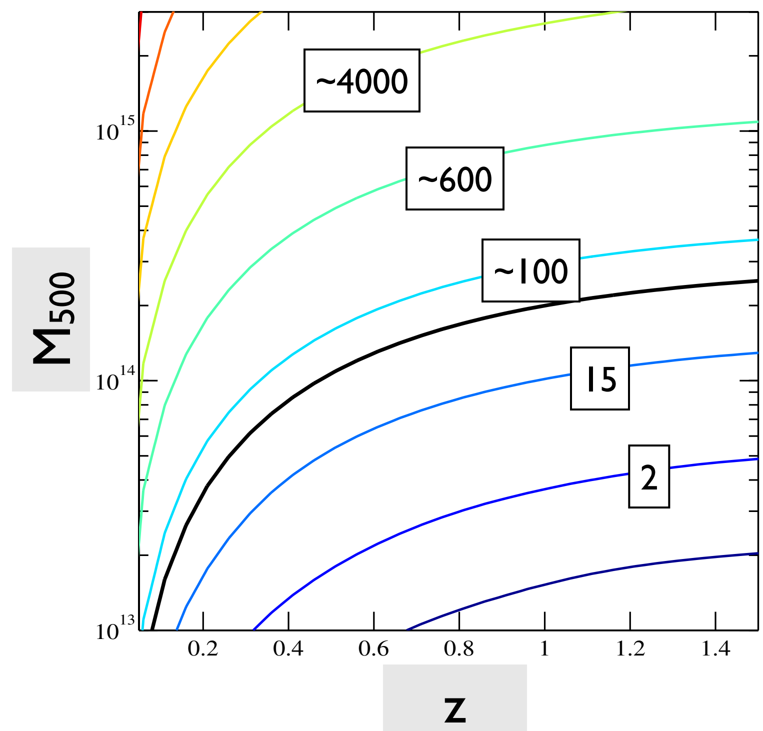
[c] *all-sky* survey excising ±20 deg around the galactic plane

From the Mass to the X-ray observable

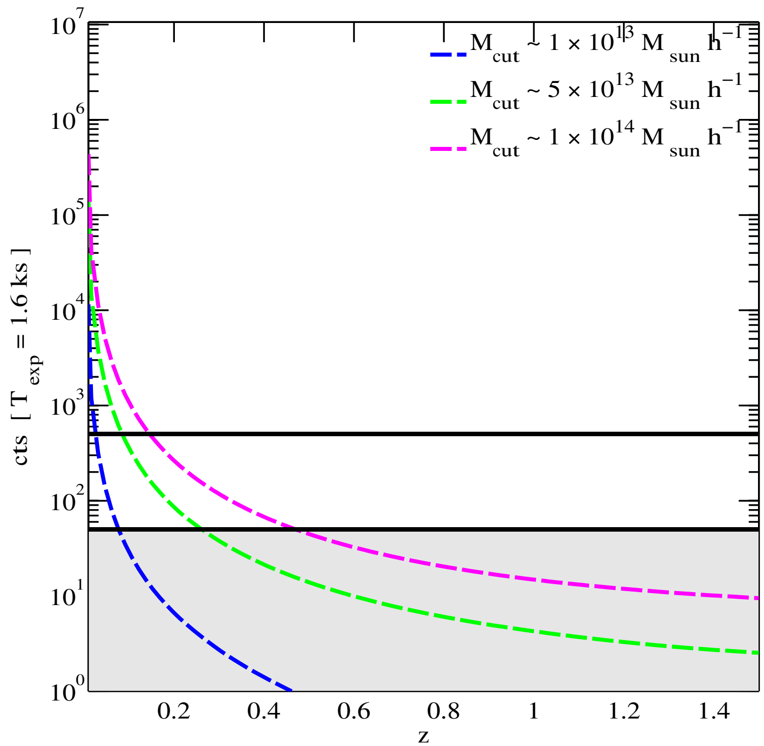


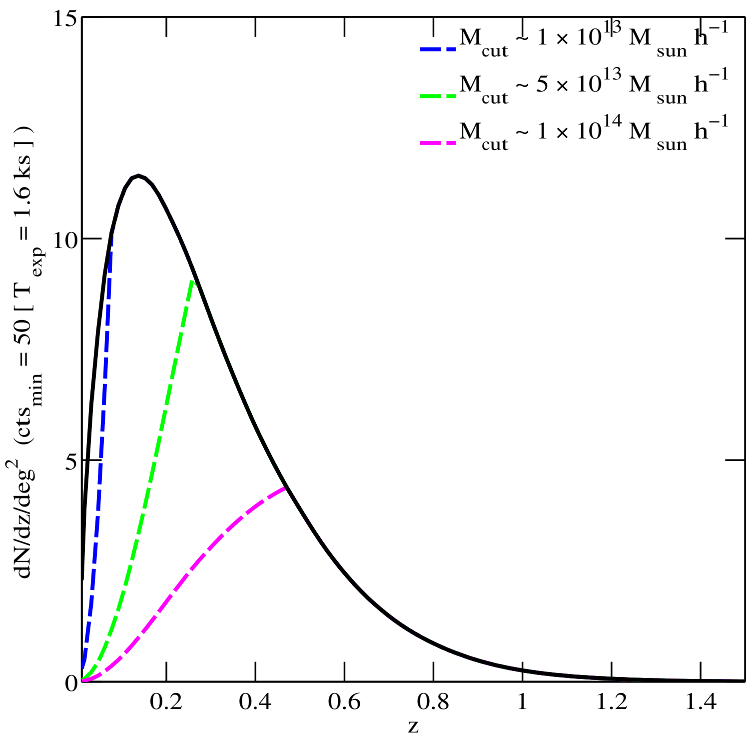






eROSITA: selections and numbers





all sky

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

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 → $f_{NL} \sim 0$, i.e. Gaussianity

BUT

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

→ $f_{NL} << 1$
$f_{NL} >> 1$

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

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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):

$$\Phi = \Phi_L + f_{NL}^{\text{local}} \cdot ((\Phi_L)^2 - \langle \Phi_L^2 \rangle)$$

Effects of local primordial non-Gaussianity

I) Dark Matter Halo Mass Function

⇨ Abundances of clusters

II) Dark Matter Halo Bias

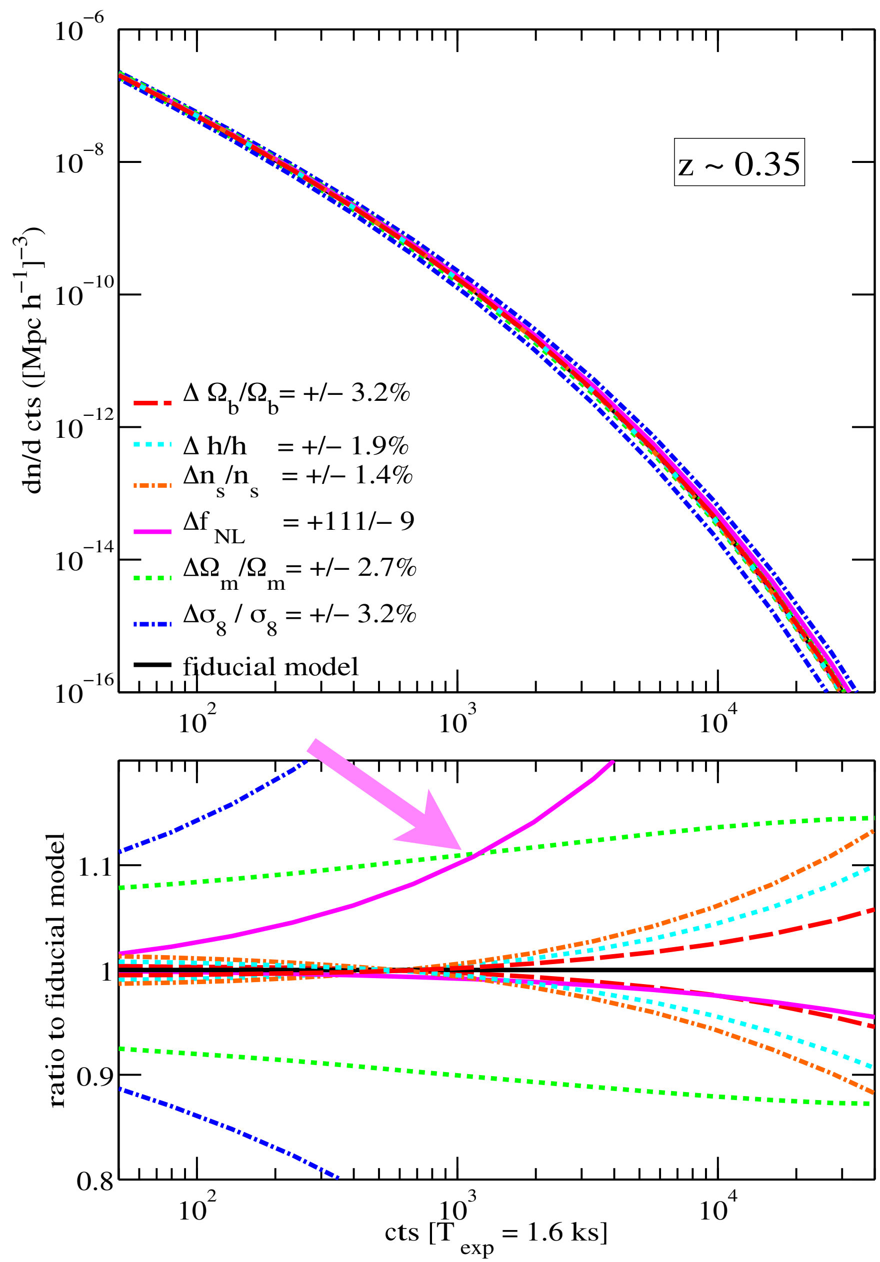
⇨ Spatial clustering of clusters

Cluster abundances

larger values of f_{NL}

↓

higher abundances of most massive haloes

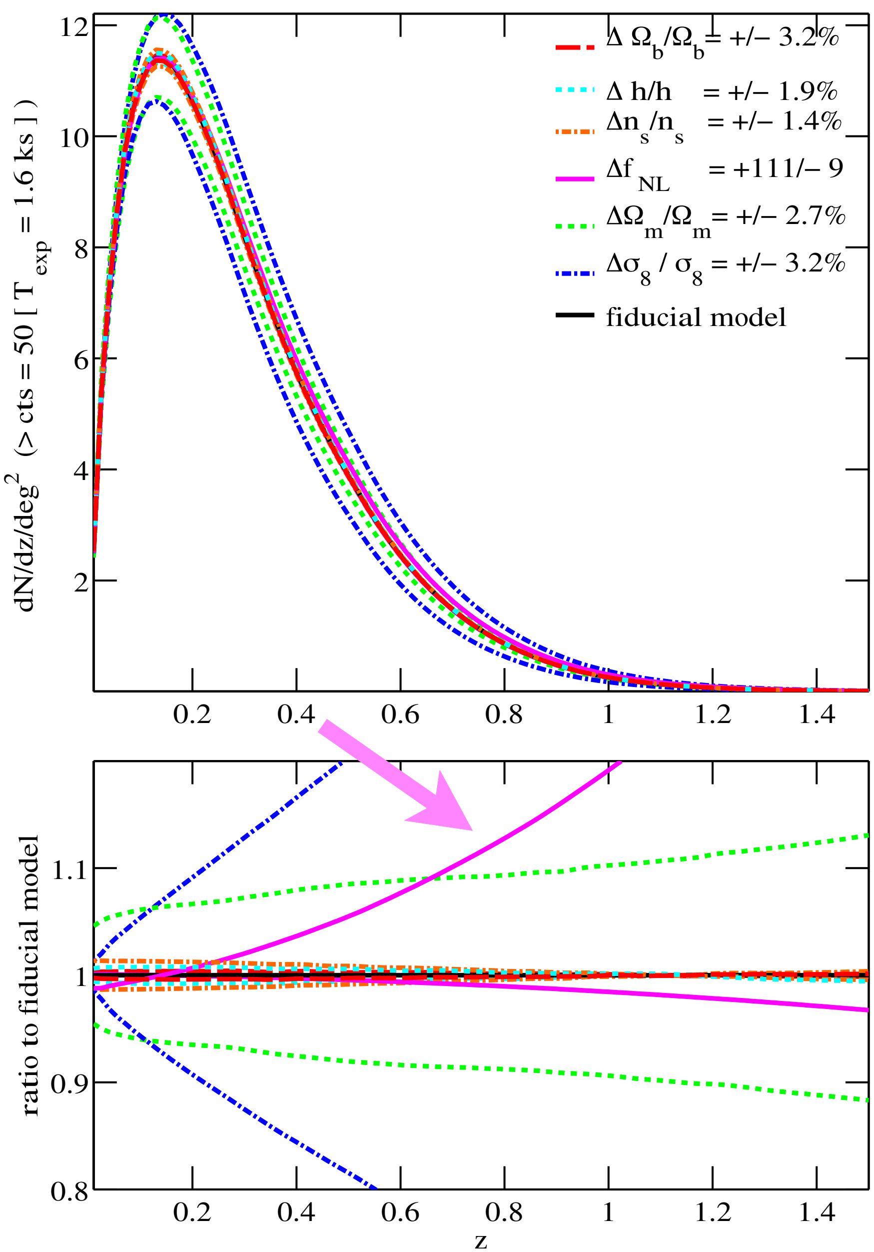


Cluster abundances

higher redshifts

↓

higher relative effect of primordial NG

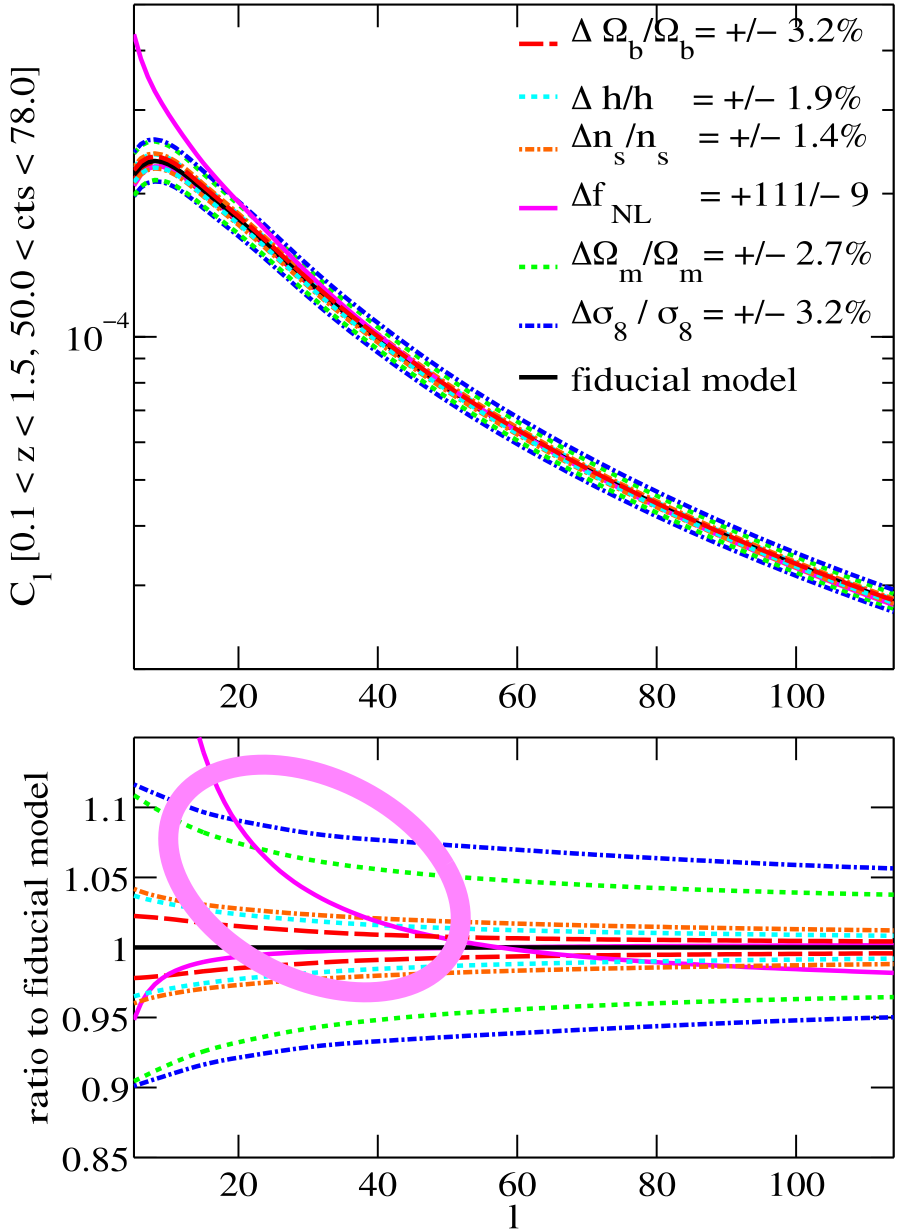


Angular Clustering

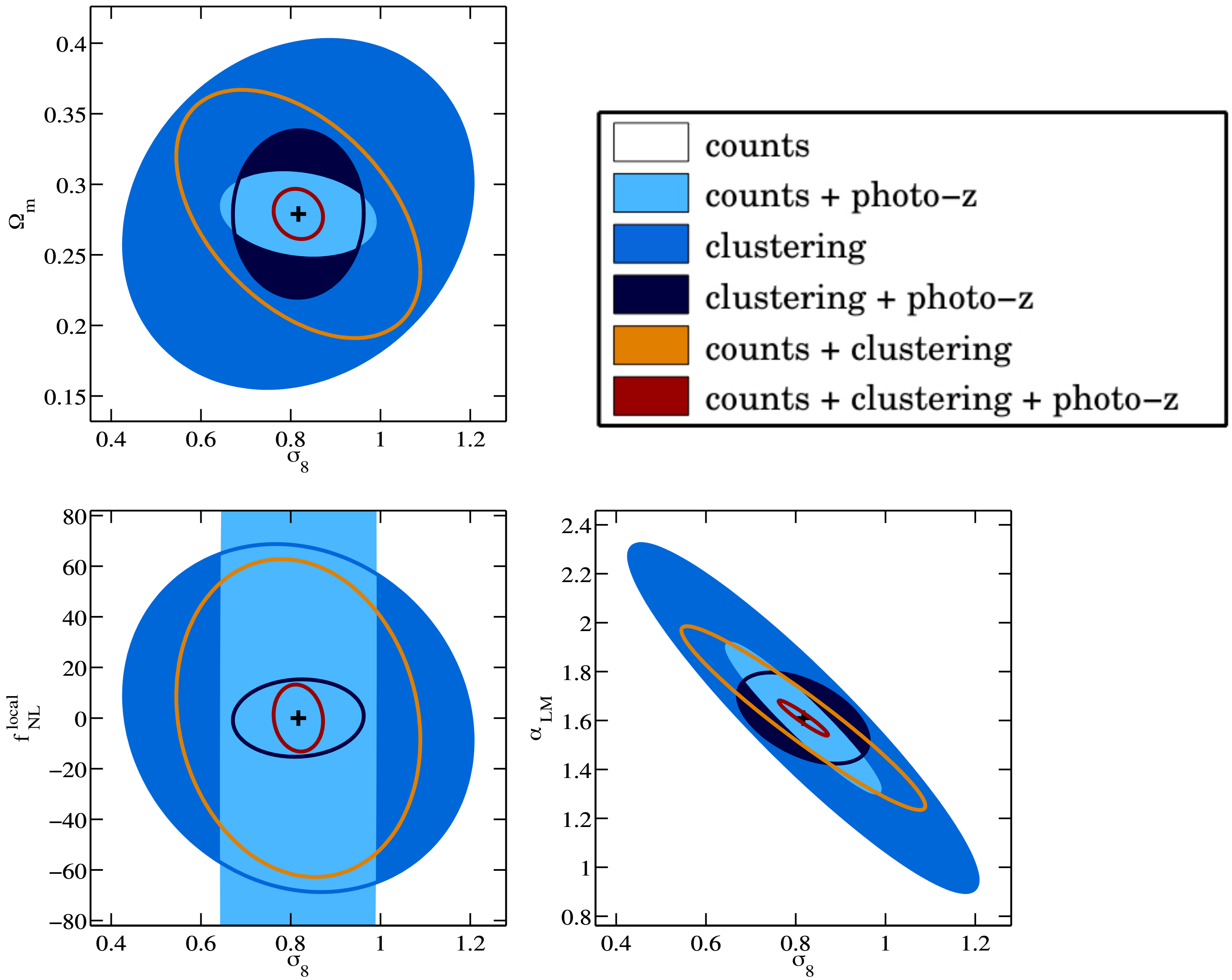
f_{NL} ~=0

↓

scale-dependent signature!!!



Results with eROSITA: self-calibration



T_{exp} = 1.6 ks

Results with eROSITA: self-calibration

eROSITA data	FoM	Δf_{NL}^{local}	$\Delta\sigma_8$	$\Delta\Omega_m$	Δn_s	Δh
Counts	1.0	$\sim 9 \times 10^3$	$\sim$ 1.6	$\sim$ .5	$\sim$ 4	$\sim$ 4
Counts + photo-z	10.7	423	.113	.0191	.559	.558
Clustering	7.1	46	.257	.0817	.845	$\sim$ 1
Clustering + photo-z	12.0	10.1	.097	.0393	.264	.299
Counts + Clustering	10.6	42	.180	.0582	.530	.967
Counts + Clustering + photo-z	16.3	8.8	.036	.0118	.088	.153
Counts + Clustering + photo-z + HSTKeyProject	16.6	8.3	.036	.0114	.048	.0709
Counts + Clustering + photo-z + PlanckI	21.3	7.6	.003	.0025	.008	.007
Counts + Clustering + photo-z + PlanckII	21.3	7.3	.027	.0047	.003	.004
Counts + Clustering + photo-z + PlanckIII	-	7.2	.004	.0065	.002	.008
Current Errors[a]	-	[-9,+111]	.026	.0073	.013	.013

+ Ω_b and X-ray scaling relation parameters ...

With eROSITA, we will get very good constraints on the local primordial non-Gaussianity, also without Planck!!!

T_{exp} = 1.6 ks

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But... what if... ?

Playing in the parameter-space

Surveys	area (deg^2)	$T_{\rm exp}$(ks)	$N_{\rm objects}$	$\Delta f_{\rm NL}^{\rm local}$	FoM$^{\rm Cosmo}$	FoM$^{\rm ICM}$
eROSITA	27'000	1.6	9.32×10^4	8.8	8.0	5.3
Deeper *eROSITA*	27'000	3.0	1.61×10^5	6.5	8.6	5.6
Focussed *eROSITA*	6'000	7.5	6.85×10^4	21.1	6.4	4.3
1/2 *eROSITA*	13'500	1.6	4.66×10^4	18.9	6.5	4.6
(1/2 + 1/2) *eROSITA*	27'000	1.6	9.32×10^4	13.4	7.3	5.1
$z \leqslant 1$ *eROSITA*	27'000	1.6	9.19×10^4	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	9×10^3	4×10^4	2×10^4
Counts + photo-z	423	2×10^3	1×10^3
Angular Clustering	46	461	1.4×10^3
Angular Clustering + photo-z	10.1	102	1.3×10^3
Counts + Angular Clustering	42	317	1.1×10^3
Counts + Angular Clustering + photo-z	8.8	36	144
WMAP7 2-σ Intervals 2011	[-10, 74]	[-410, 6]	[-214, 266]

bias $\propto k^{-2}$ | bias $\propto k^{-1}$ | bias $\propto$ const

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

.... more details on Pillepich et al. 2011

Concluding...

- With eROSITA, good constraints on the primordial non-Gaussianity will be obtained, also with self-calibration.

- 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**

Thanks!