COSMOLOGY WITH GALAXY CLUSTERS

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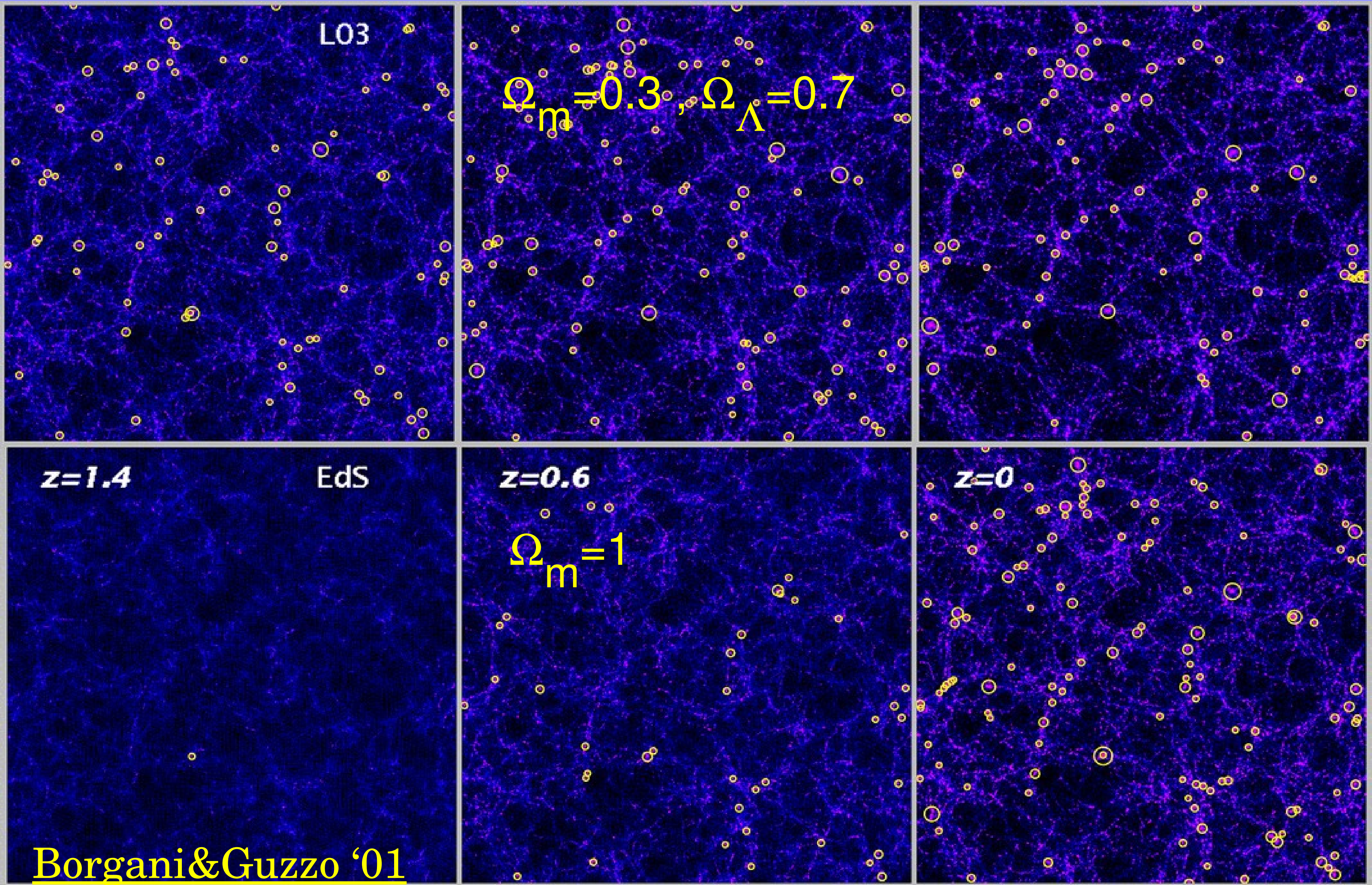
in collaboration with S. Borgani

Bertinoro, 27 May 2009

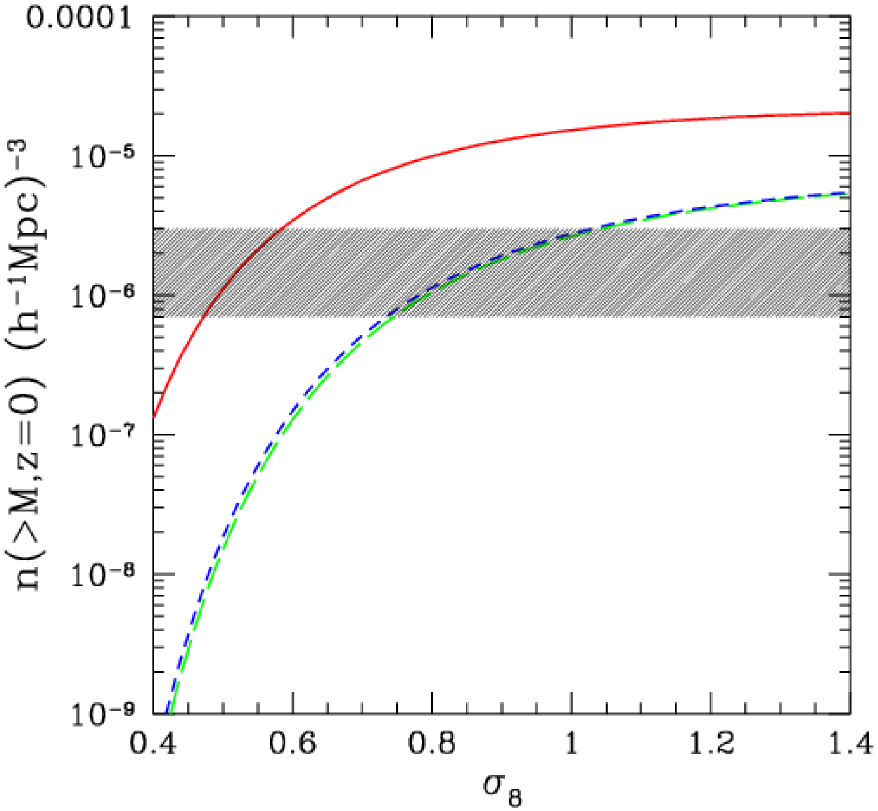
Evolution of galaxy clusters



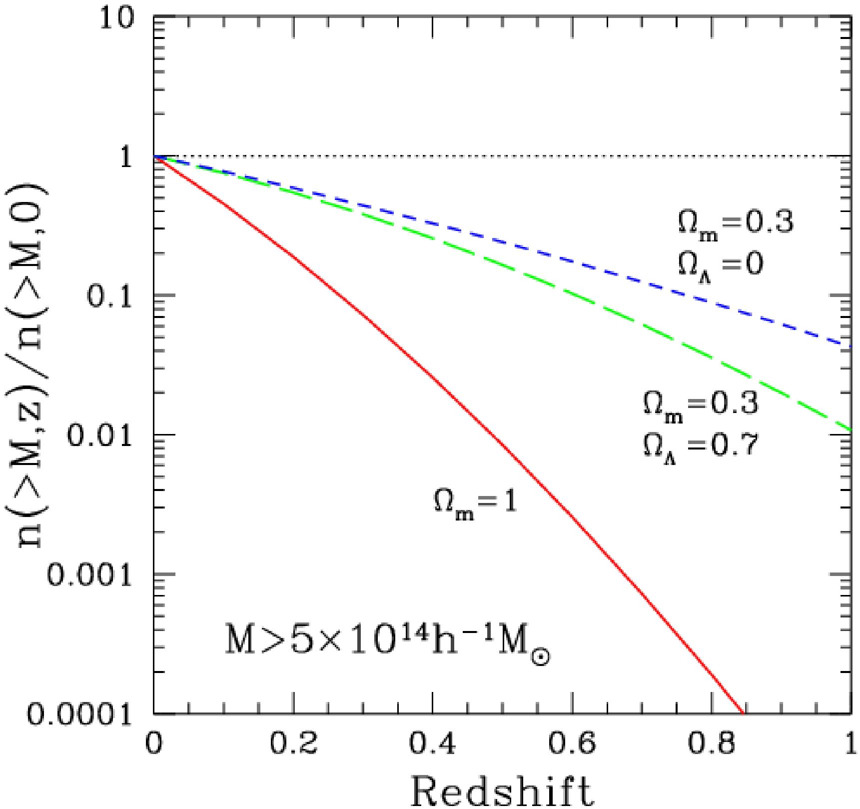
Borgani&Guzzo '01

The mass function as a cosmological test

Changing the P(k) normalization



Changing the density parameter



Rosati et al 2002

Mass function: Press & Shechter approach

Assumptions: Spherical collapse

Gaussian distribution of primordial density fluctuations

$$n(M)dM = -\frac{2}{V_R}\frac{\partial p(\delta_c, M))}{\partial M}dM = \sqrt{\frac{2}{\pi}}\frac{\rho}{M^2}\frac{\delta_c(z)}{\sigma_M}\left|\frac{dlog\sigma_M}{dlogM}\right|exp\left(-\frac{\delta_c(z)^2}{2\sigma_M^2}\right)dM$$

- $p(\delta_c,M)$: Gaussian probability for a perturbation of mass M to exceed δ_c
- $D(z)=D(\Omega_m,\Omega_{DE},\omega)$: linear growth rate of density fluctuations
- $\delta_c = \delta_c(z)$ critical density constrast for spherical collapse (=1.69 for EdS)
- variance at the mass scale M linearly extrapolated at redshift z for the filter function $W_M(k)$:

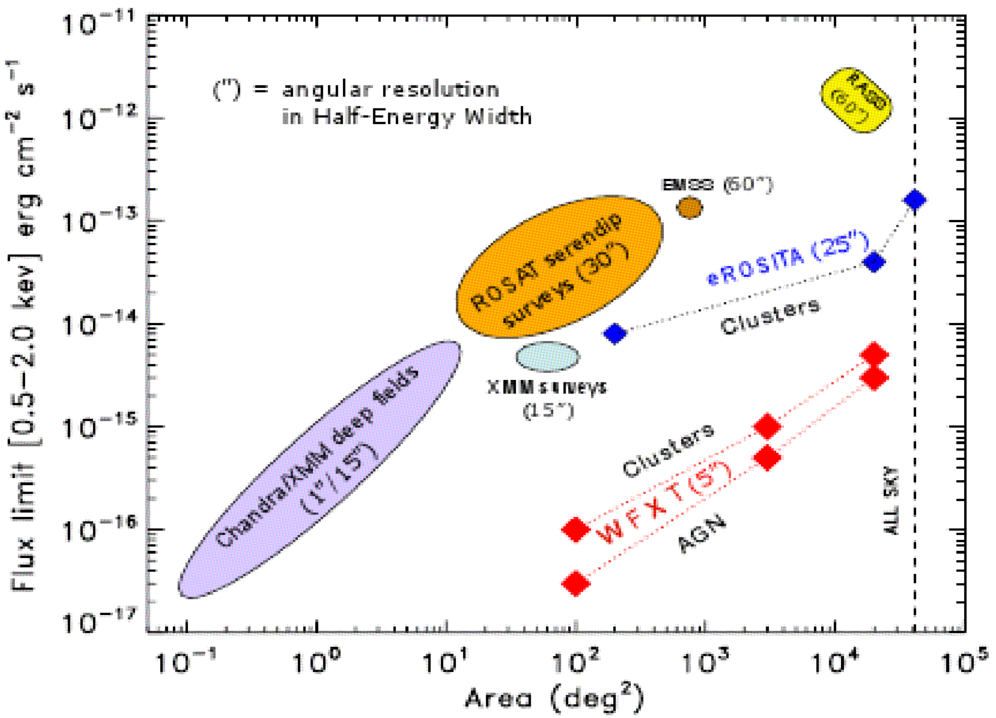
$$\sigma_M^2(z) = \frac{D^2(z)}{2\pi^2}\int_0^\infty dk k^2 P(z) W_M^2(k)$$

The Wide Field X-Ray Telescope (WFXT)

US: JHU, Marshall, CfA - Italy: ASI/INAF (Milano, Trieste, Bologna, Napoli, Rome)

Whitepaper on Cluster Science submitted to the Decadal Survey:

R. Giacconi et al.: Galaxy Clusters and the Cosmic Cycle of Baryons across Cosmic Times (arXiv: 0902.4857)



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WFXT survey parameters (0.5-2.0 keV band)

Quantity	Survey		
	Deep	Medium	Wide
Ω (deg^2)	100	3000	20,000
Exposure	400 ksec	13 ksec	4 ksec
Total Time	1 yr	2 yr	2 yr
S_{min} point erg s^{-1} cm^{-2}	3×10^{-17}	5×10^{-16}	3×10^{-15}
Tot. AGN	5×10^5	4×10^6	1×10^7
S_{min} extended erg s^{-1} cm^{-2}	1×10^{-16}	1×10^{-15}	5×10^{-15}
Tot. Clusters/Groups	5×10^4	3×10^5	5×10^5

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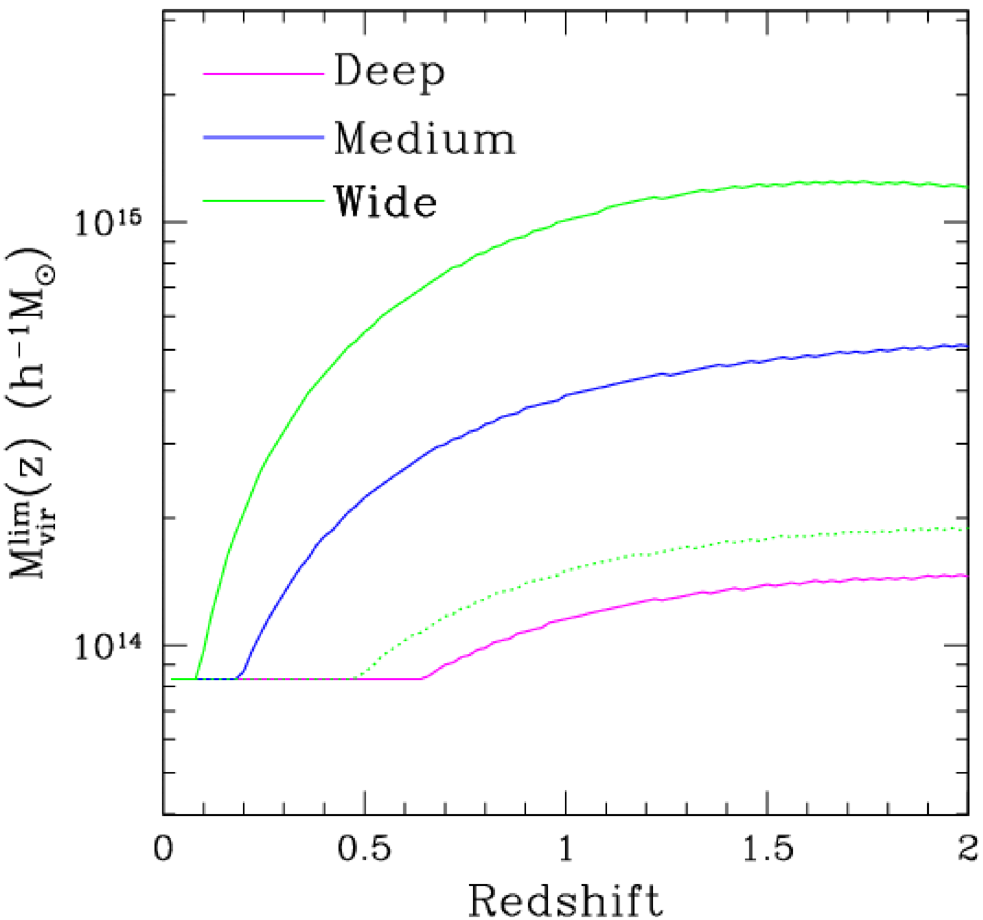
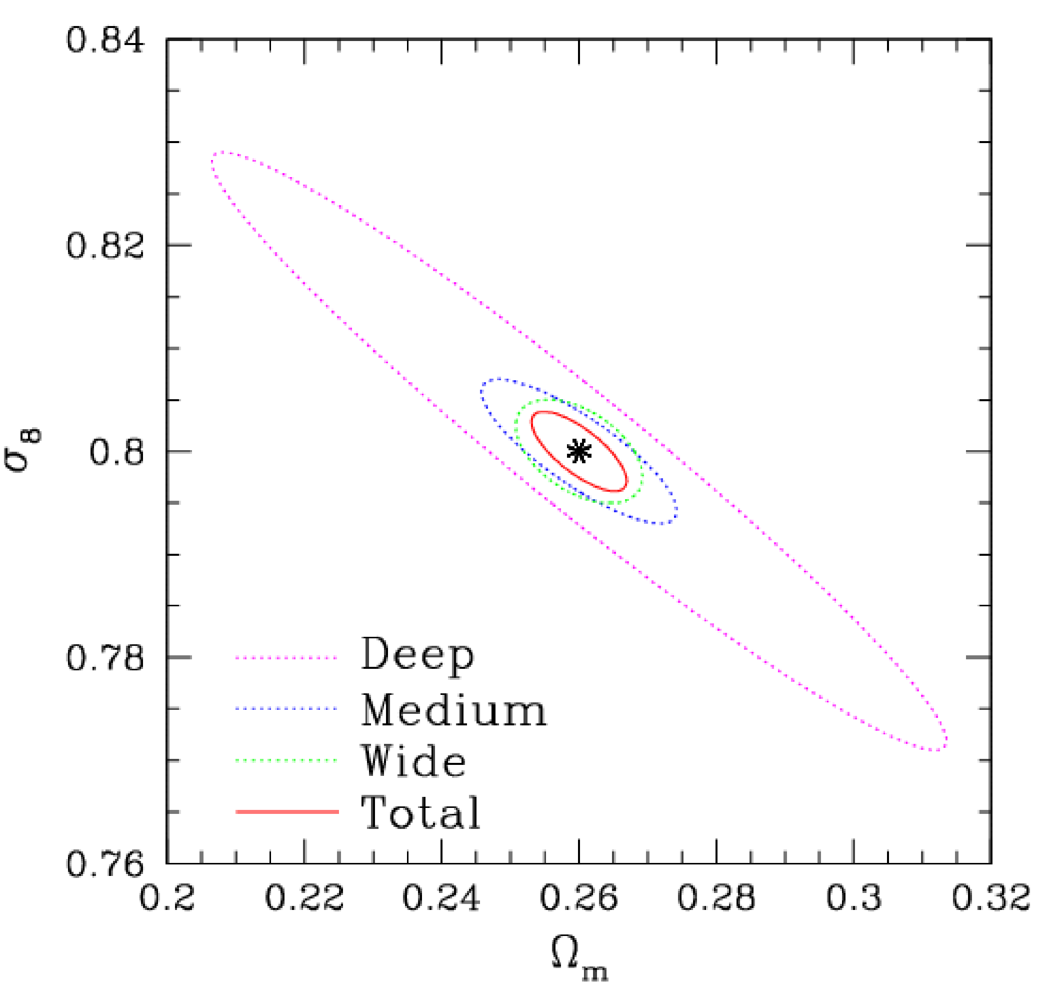
Constraints on cosmological parameters

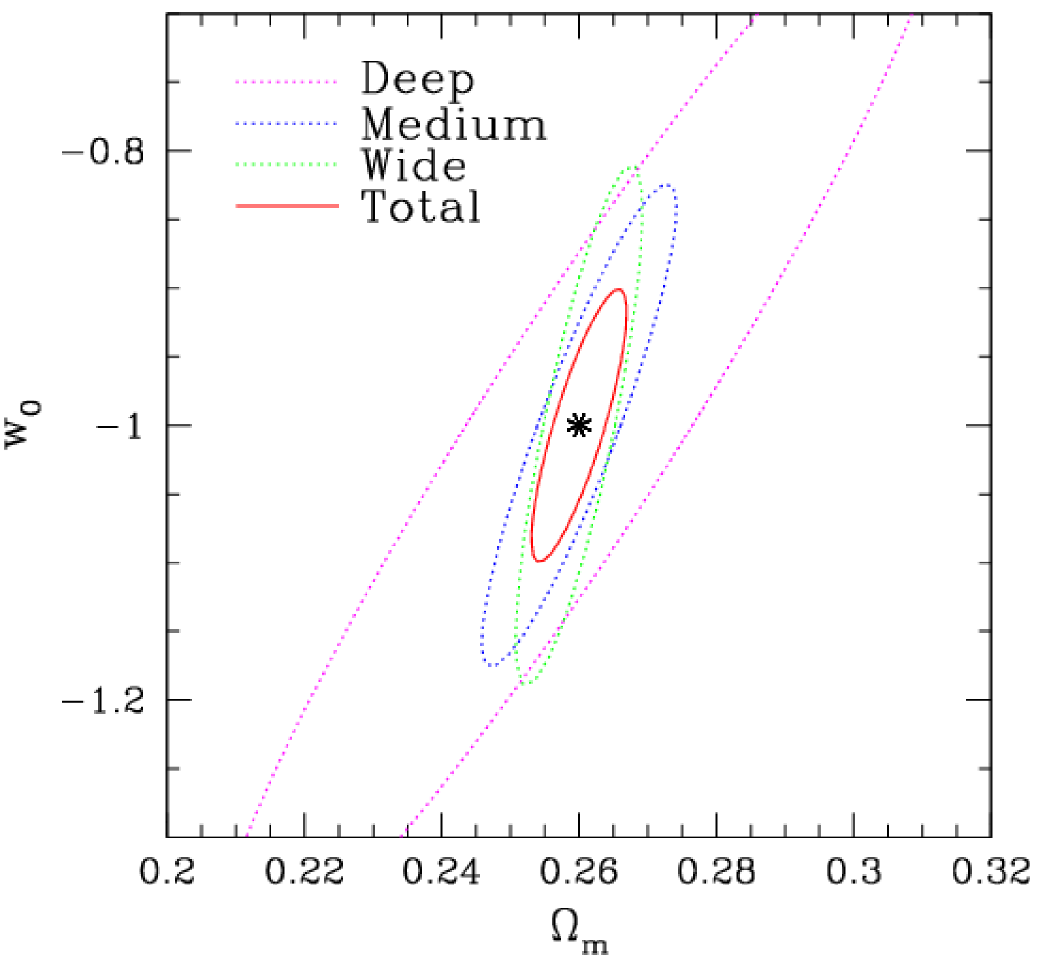


- limit mass virialization varing with redshift
- Sheth & Tormen mass function
- top-hat window function
- transfer function: Bardeen et al 1986 with corrections Sugiyama for barions.
- Fisher matrix method
- fiducial values from WMAP-5
- flat prior

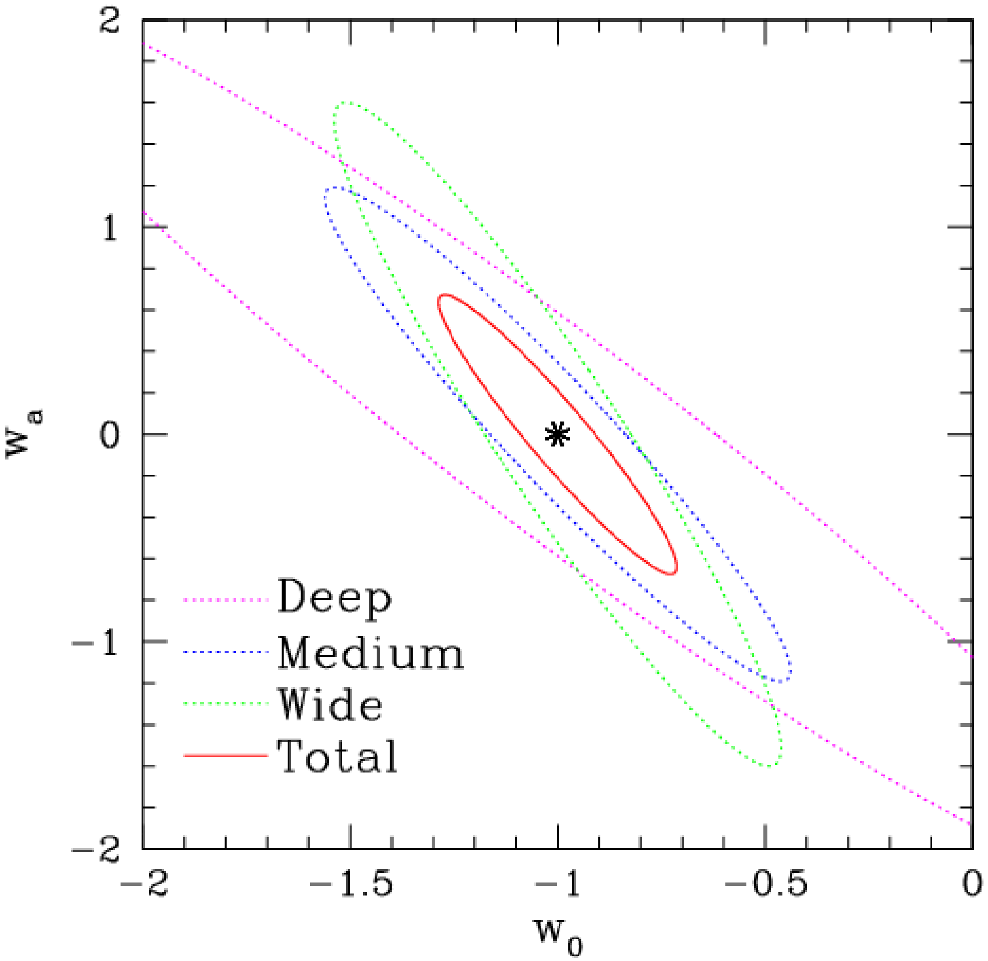
Constraints on cosmological parameters



Constraints on cosmological parameters

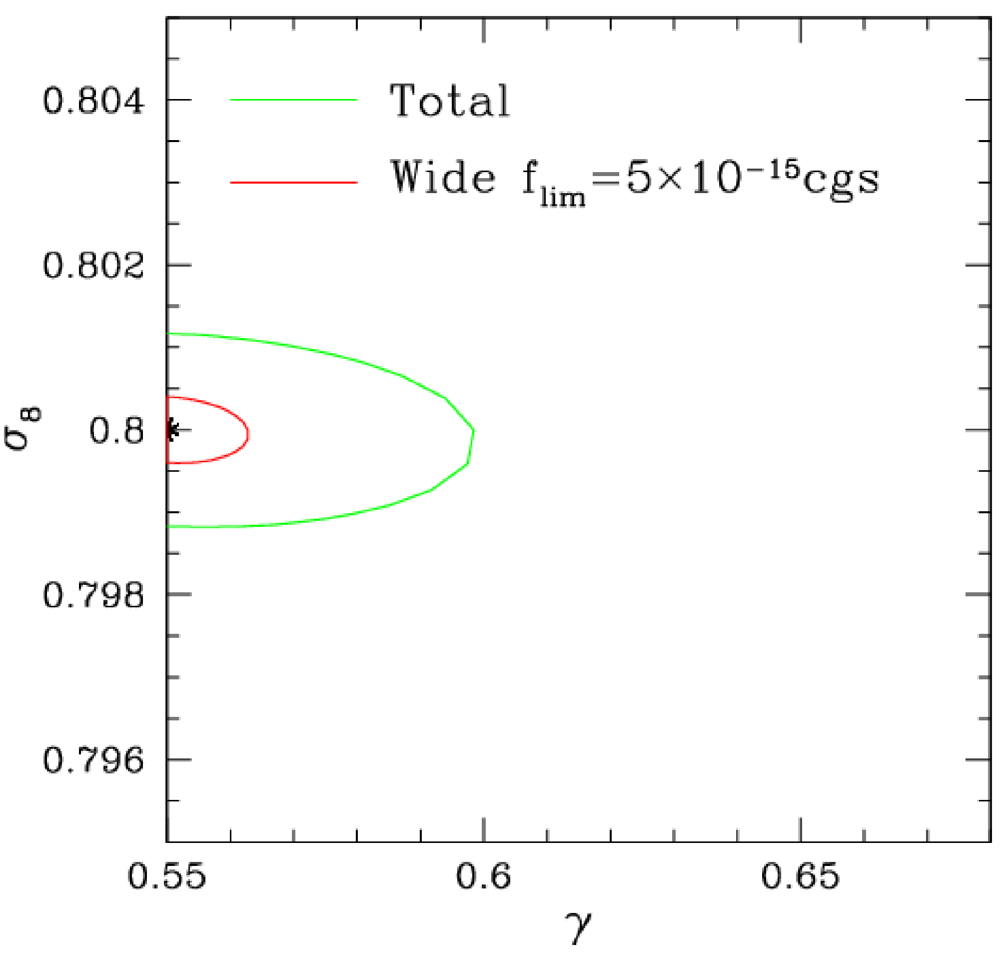


Constraints on cosmological parameters



$$w(a) = w_0 + (1-a)\, w_a$$

Constraints on cosmological parameters



- Parametrize deviations from GR with:

$$\frac{d\ln\delta}{d\ln a} = \Omega_m(a)^\gamma$$

$\gamma=0.55$: standard GR

Future developments

- modifications of GR theory
- non-gaussian primordial fluctuations

Thank you

Selection functions of WFXT surveys

• Take F_{lim} corresponding to 1500 photons:

pPrecise determination of redshift

¤Robust mass proxy (e.g. $Y_X=T_{500}M_{gas}$; Kravtsov et al. 06)

• Use the observed L_X-M_{500} relation (Maughan et al. 07)

• Deep survey to calibrate the Y_X-M_{500} relation down to F_{lim} for detection in the Wide Survey

• Only using clusters dN/dz;

• Assume flat prior;

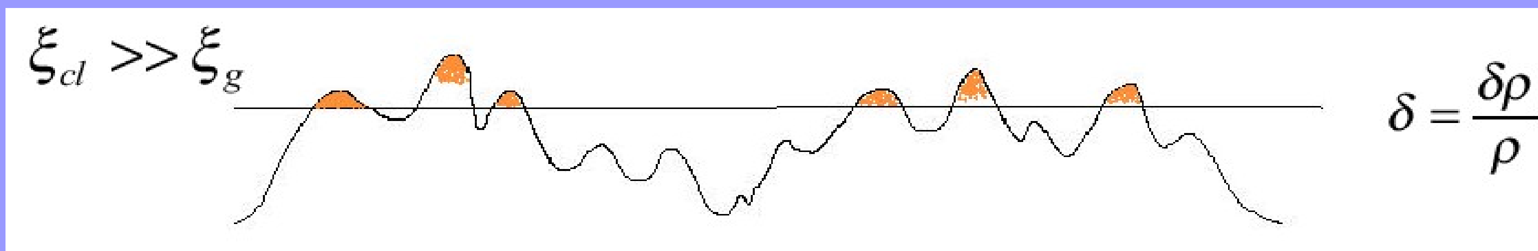
• Flux limits for precise mass proxy (i.e. avoid self-calibration);

(¤Most of constraining power on Wide & Medium surveys.

The large-scale clustering of galaxy clusters

• Galaxy clusters form in correspondence of high-density regions of the primordial fluctuation field (Kaiser 1984, Bardeen et al. 1986)

• They are <u>amplified tracers</u> of cosmic inhomogeneities.



$\xi_{DM}(r, z)$: correlation function of Dark Matter

$\xi_{cl}(r, z, M)$: correlation function for clusters

$$\xi_{cl}(r, z, M) = b^2(z, M)\,\xi_{DM}(r, z)$$

b(M,z): bias factor Measure of the clustering amplification induced by the process of selective structure formation; in general Mass- and redshift-dependent.

The large-scale clustering of galaxy clusters

- x x Kaiser '84: clusters form in correspondence of high-density peaks:

$$b(M,z) = \delta_c(z)/\sigma^2(R_M,z)$$

- Mo & White '96: halo clustering in Eulerian space from extended PS approach by Bond et al. '91:

$$b(M,z) = 1 + \frac{\left[d_c(z)/s(R_M,z)\right]^2 - 1}{d_c(z)}$$

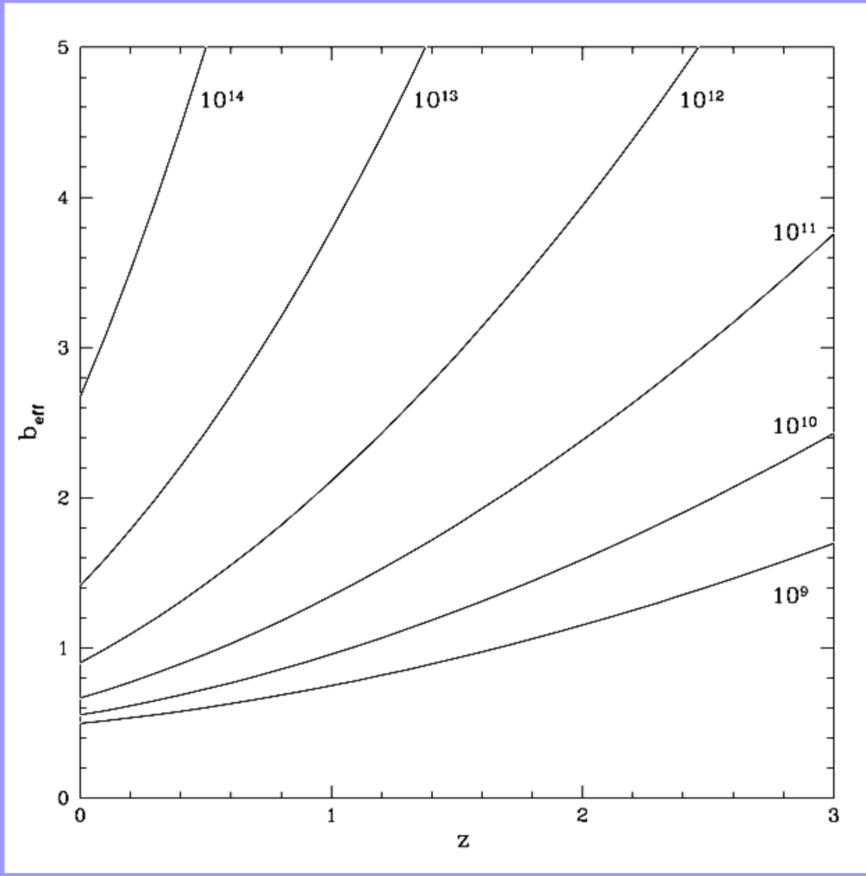
- Sheth & Tormen '99: peak-background splitting applied to MW96

$$b(M,z) = 1 + \frac{a\left[d_c(z)/s(R_M,z)\right]^2 - 1}{d_c(z)} + \frac{2\mathrm{p}/d_c(z)}{1 + \left[a\left[d_c(z)/s(R_M,z)\right]^2\right]^p}$$

$$a = 0.707 \quad ; \quad p = 0.3$$

- In practical applications we deal with a population of objects with <u>mass above a limiting value:</u>

$$b_{eff}(M,z) = \frac{\int_M^\infty dM'\, b(M',z)\, n(M',z)}{\int_M^\infty dM'\, n(M',z)}$$



- For a flux-limited (F_{lim}) sample of clusters:

(a) Estimate for each redshift

$$L = 4\pi d_L(z)^2 F_{lim}$$

(b) Convert L into M_{lim}

(c) Compute b_{eff} as a fct. of z

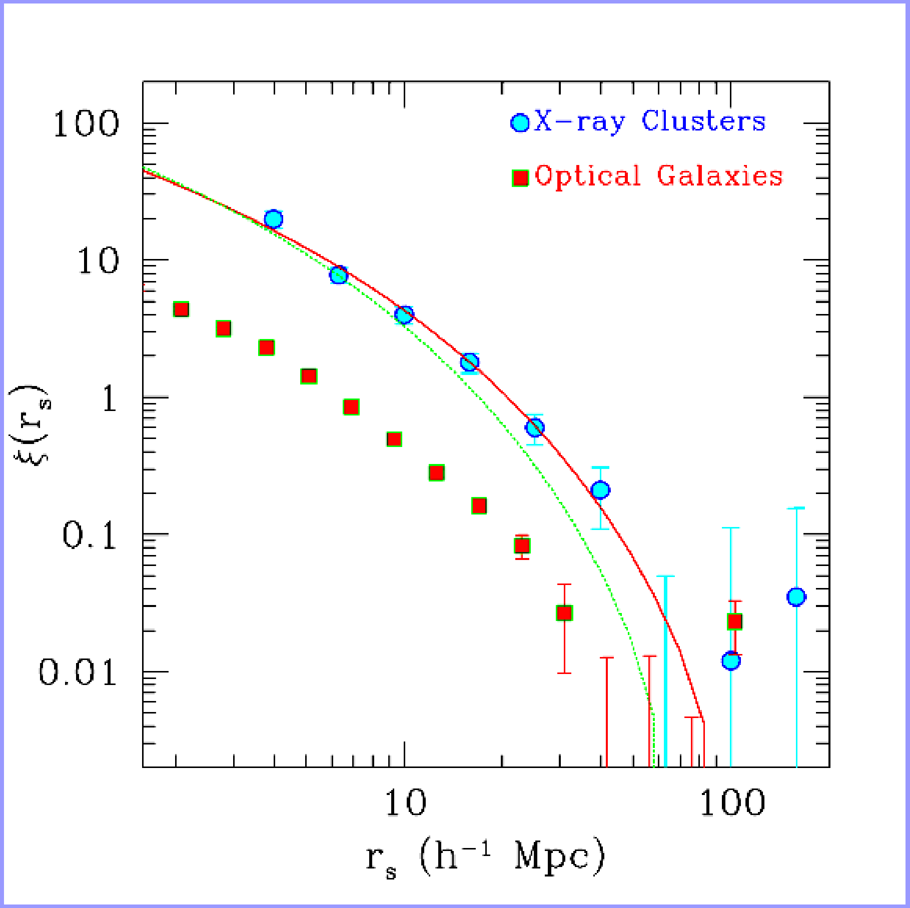
Higher-z objects are rarer

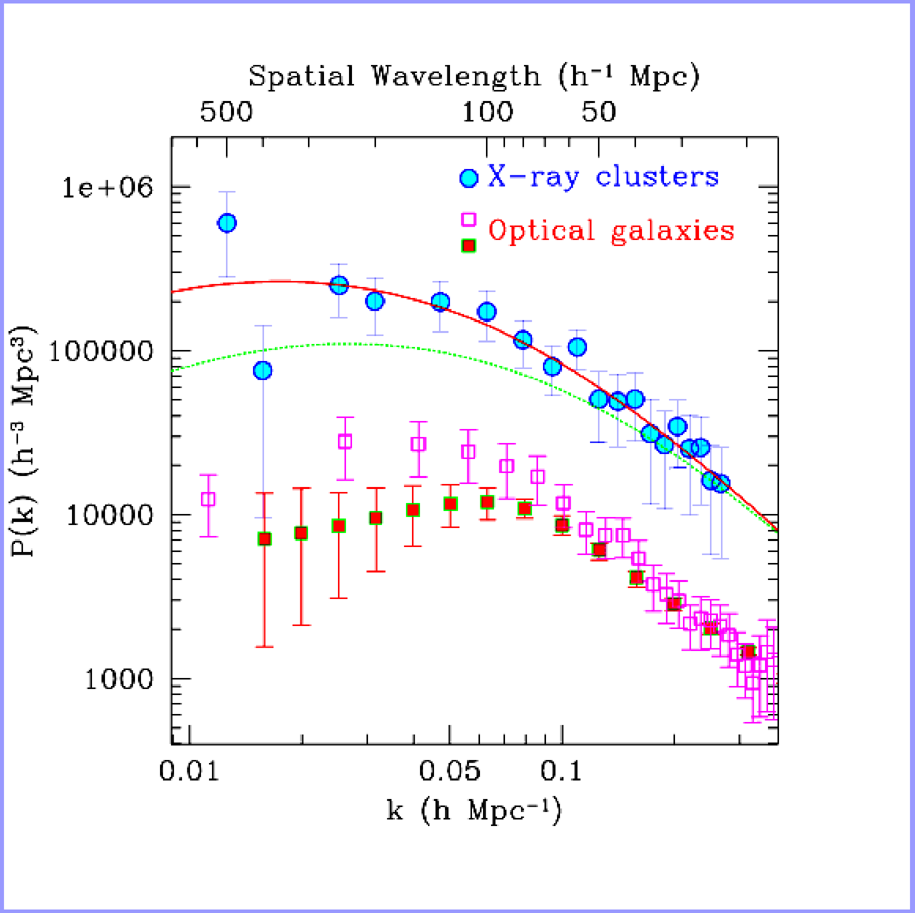
→ larger b_{eff} at high redshift

Matarrese et al. (1996): $\Omega_m=1$, $\Gamma=0.25$, $\sigma_8=0.6$

The large-scale clustering of galaxy clusters

SB & Guzzo '01





$\xi(r) \Rightarrow$ Collins et al. (2000) Ω_m=0.3 , Ω_Λ=0.7 , CDM

$P(k) \Rightarrow$ Schuecker et al. (2000) Ω_m=0.5 , Ω_Λ=0.5 , CDM

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- Characterize ICM properties and measure mass proxies for thousands of clusters at z>1.
- Trace the epoch of entropy injection and metal enrichment of the ICM.
- Study the intense dynamics of proto-cluster assembly at z~2.

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See also talksby P. Rosati & P. Tozzi

QuickTimeª and a
decompressor
are needed to see this picture.

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