Optimizing the XXL survey design for cluster cosmological studies

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Abstract

Our goal is to constrain the cosmological parameters (in particular Ω_M , σ_8 and H_0) *using only* clusters of galaxies in a self-sufficient approach. A Fisher analysis for various survey configurations (50 deg^2 or 200 deg^2, with 10 ks XMM exposures) allows us to point out the critical trends in the cosmological parameter determination. In particular, we investigate the respective roles of the survey area and of the accuracy of the cluster mass determination.

Our analysis shows that (1) the cluster-cluster correlation function provides critical constraints in the self-sufficient analysis and (2) that a 50 deg^2 survey with a cluster mass accuracy of 10% provide constraints ($\delta\Omega_M$ < 10% and $\delta\sigma_8$ ~ 5%) comparable to that of a 200 deg^2 survey with 50% mass accuracy.

Working hypotheses

We used the following parameters in the analysis,

free parameters: h, Ω_M, Ω_Λ, σ_8

where h is the reduced cosmological constant ($h=H_0/(100$ km/s/Mpc$)$, Ω_M is the matter density, Ω_Λ is the cosmological constant density, σ_8 is the normalisation of the matter power spectrum, α quantifies our knowledge on the precision of mass measurements. We suppose that we don't know the cluster masses M but only αM, α being a free parameter *a priori* known at a given precision (unknown, 10%, 50%, perfectly known).

Our fiducial model for the Fisher analysis is based on WMAP3 data: h=0.73, Ω_M=0.24, Ω_Λ=0.76, σ_8=0.74 and we choose α=1.

The baryon density is fixed to Ω_B=0.04 and the matter power spectrum shape Γ is computed using the Sugiyama (1995) formula: $\Gamma=\Omega_M\, h \exp[-\Omega_B(1+\mathrm{sqrt}(2h)/\Omega_M)]$.

We used two measurements to constrain the parameters: dN/dz and ξ where dN/dz is the cluster number counts as a function of redshift z and ξ, the correlation function of the survey.

In all what follows, the selection function of the surveys is assumed to be the XMM-LSS Class 1 selection function (see figure 0) as defined in Pacaud et al. (2007). The density of Class 1 clusters is ~ 6 deg^{-2} in our fiducial model.

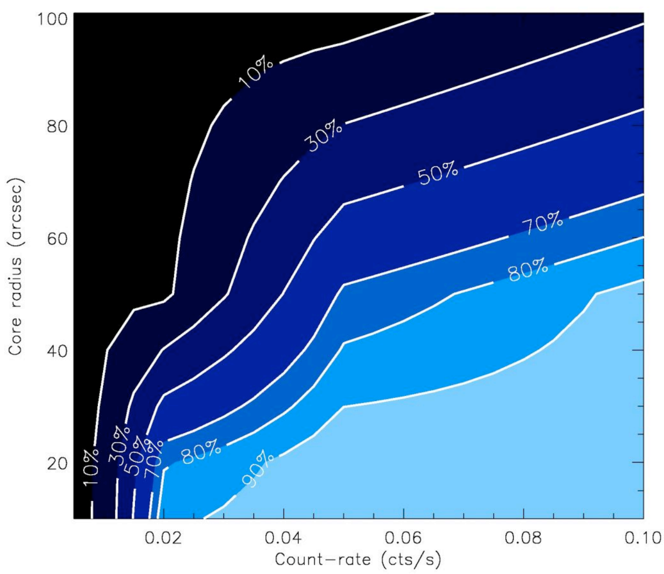

Figure 0.
The C1 cluster selection function

Selecting clusters as a function of extent and count-rate allows the construction of uncontaminated X-ray cluster samples significantly larger than a simple flux limit would allow (Pacaud et al 2007)

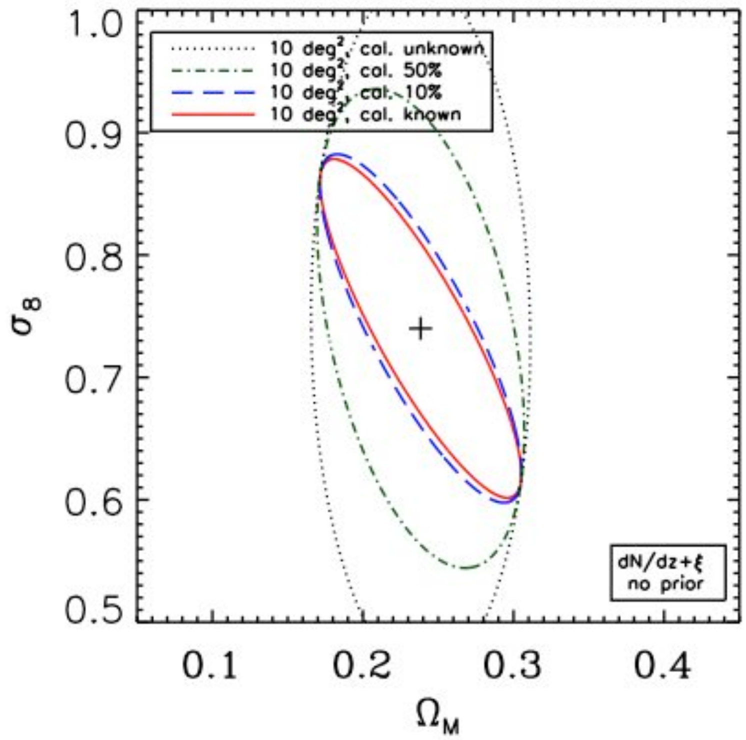

Figure 1. Constraints on σ_8 and Ω_M from a 10 deg^2 survey (current XMM-LSS)
The contours are 1σ errors when the calibration (α parameter) is unknown (dotted black line), known at 50% (dash-dotted green line), known at 10% (dashed blue line), and perfectly known (solid red line). The constraints are obtained using cluster counts dN/dz and the cluster correlation function ξ. No priors on the cosmological parameters are assumed.

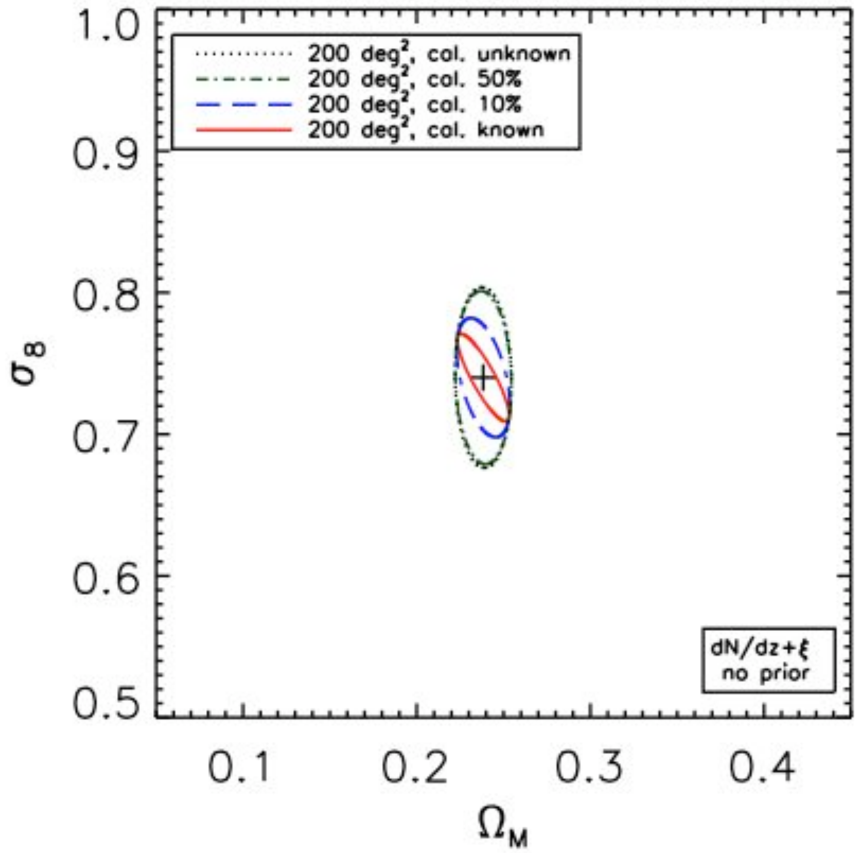

Figure 2. Constraints on σ_8 and Ω_M from a 200 deg^2 survey
The contours are 1σ errors when the calibration (α parameter) is unknown (dotted black line), known at 50% (dash-dotted green line), known at 10% (dashed blue line), and perfectly known (solid red line). The constraints are obtained using cluster counts dN/dz and the cluster correlation function ξ. No priors on the cosmological parameters are assumed.

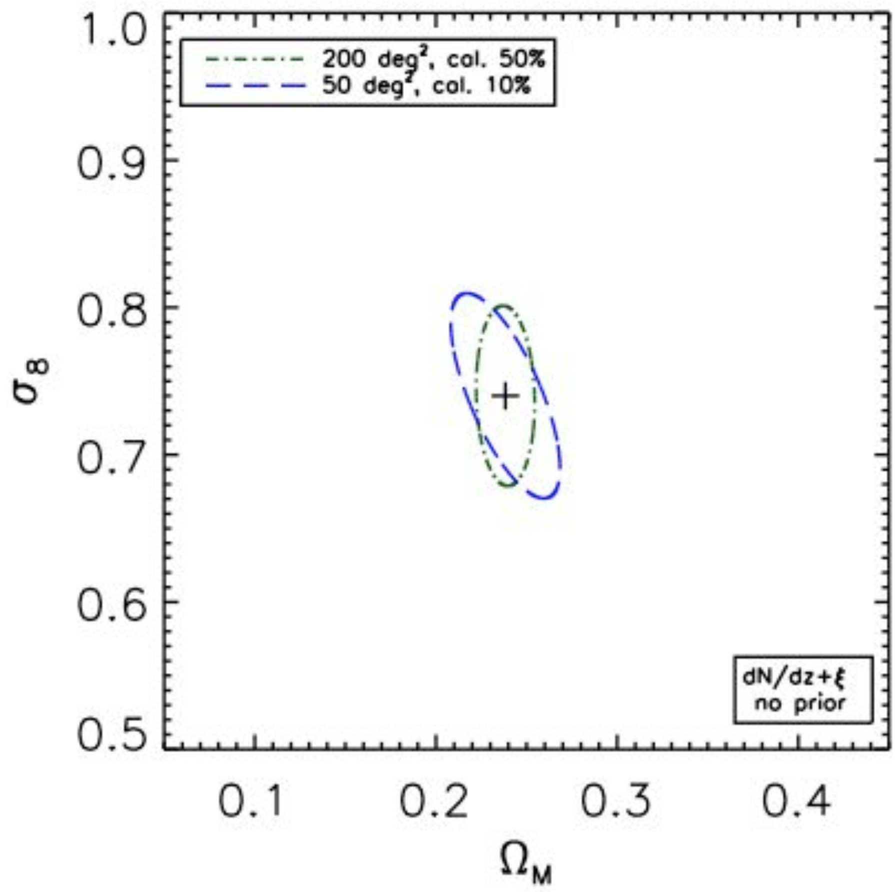

Figure 3. Constraints on σ_8 and Ω_M from a 200 deg^2 versus a 50 deg^2
The contours are 1σ errors. For the 200 deg^2 survey, the calibration parameter α is supposed to be known at 50% (dash-dotted green line) while for the 50 deg^2 survey, it is supposed to be known at 10% (dashed blue line). The constraints are obtained using cluster counts dN/dz and cluster correlation function ξ. No priors on the cosmological parameters are assumed.

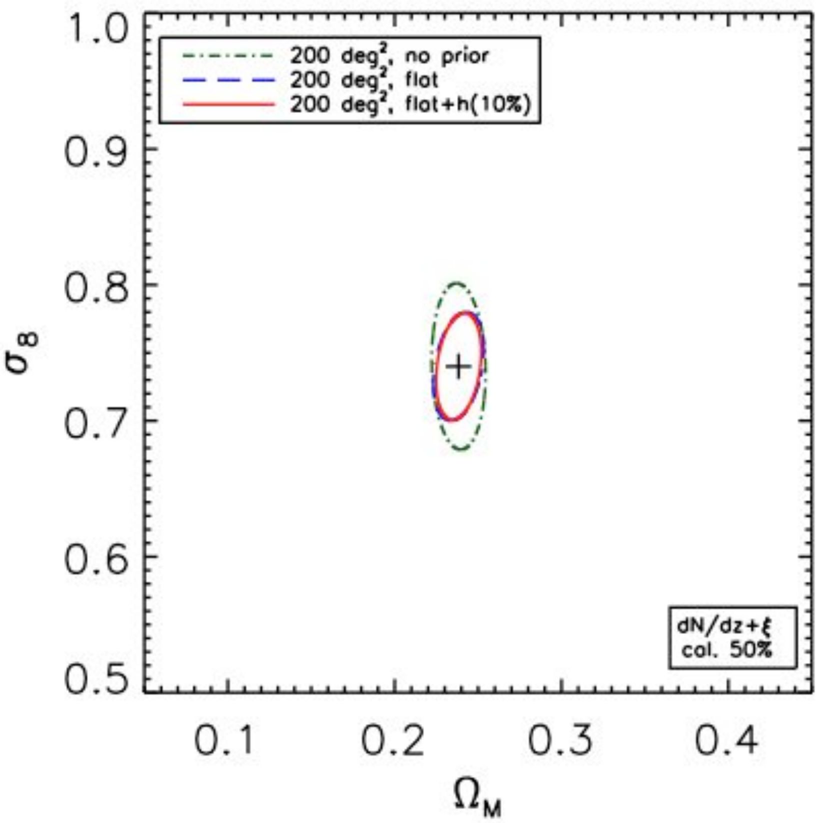

Figure 4. Constraints on σ_8 and Ω_M from a 200 deg^2 survey using weak priors
The contours are 1σ errors. Constraints are displayed assuming no prior (dash-dotted green line), assuming that the Universe is flat (dashed blue line), assuming that the Universe is flat and the Hubble constant is known with a 10% accuracy (solid red line). The constraints are obtained using cluster counts dN/dz and the cluster correlation function ξ. The calibration parameter α is supposed to be known at 50%.

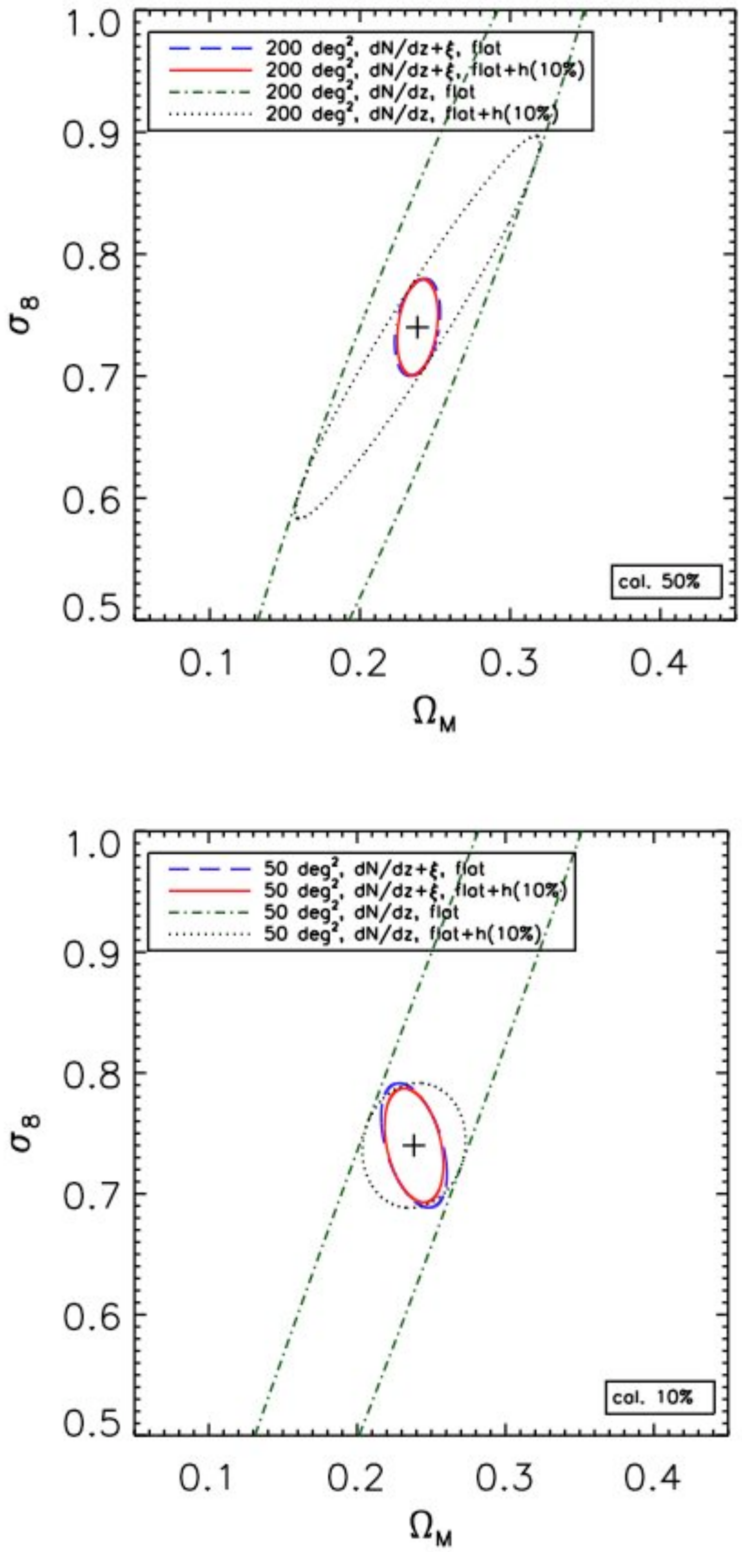

Figure 5. Constraints on σ_8 and Ω_M from a 200 or 50 deg^2 survey with and without the correlation function ξ

The contours are 1σ errors. Constraints are displayed assuming that the Universe is flat and using cluster counts and the cluster correlation function (dashed blue line), assuming that the

Universe is flat and the Hubble constant is known with a 10% accuracy and using cluster counts and the cluster correlation function (solid red line), assuming that the Universe is flat and using cluster counts only (dash-dotted green line), assuming that the Universe is flat and the Hubble constant is known with a 10% accuracy and using cluster counts only (dotted black line). The calibration parameter α is supposed to be known at 50%.
This demonstrates that in the case of a self-sufficient determination of the cosmological parameters using clusters only, the 2pt correlation function provides a decisive input.

References:

Sugiyama, N.: 1995, ApJS 100, 281
Pacaud, F. et al.: 2007, MNRAS 382, 1289