The PLANCK Cluster Catalog:
SZ/X-ray Expected Properties

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in the framework of the Planck consortium

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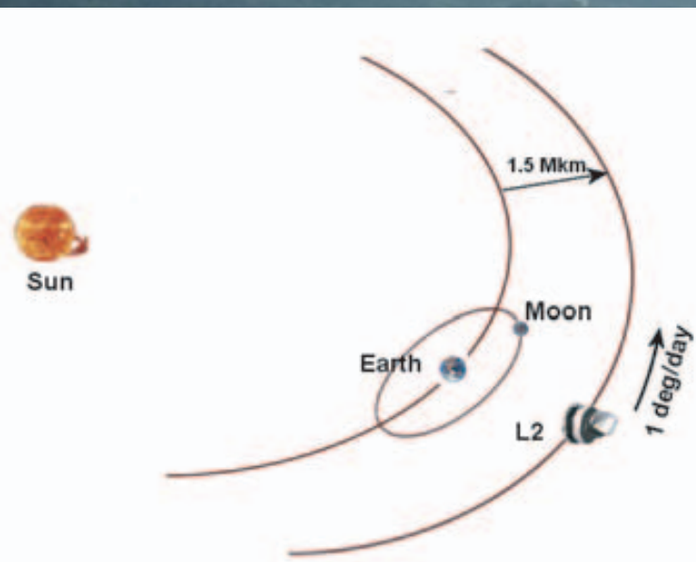
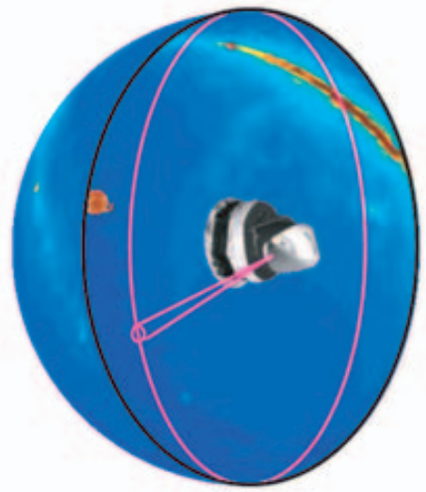
The Planck mission

Background

- Successfully launched on May 14th 2009 from Kourou
- All-sky CMB survey made from L2
- Nominal mission: 14 months (2 skies)
- Survey started on August 13th





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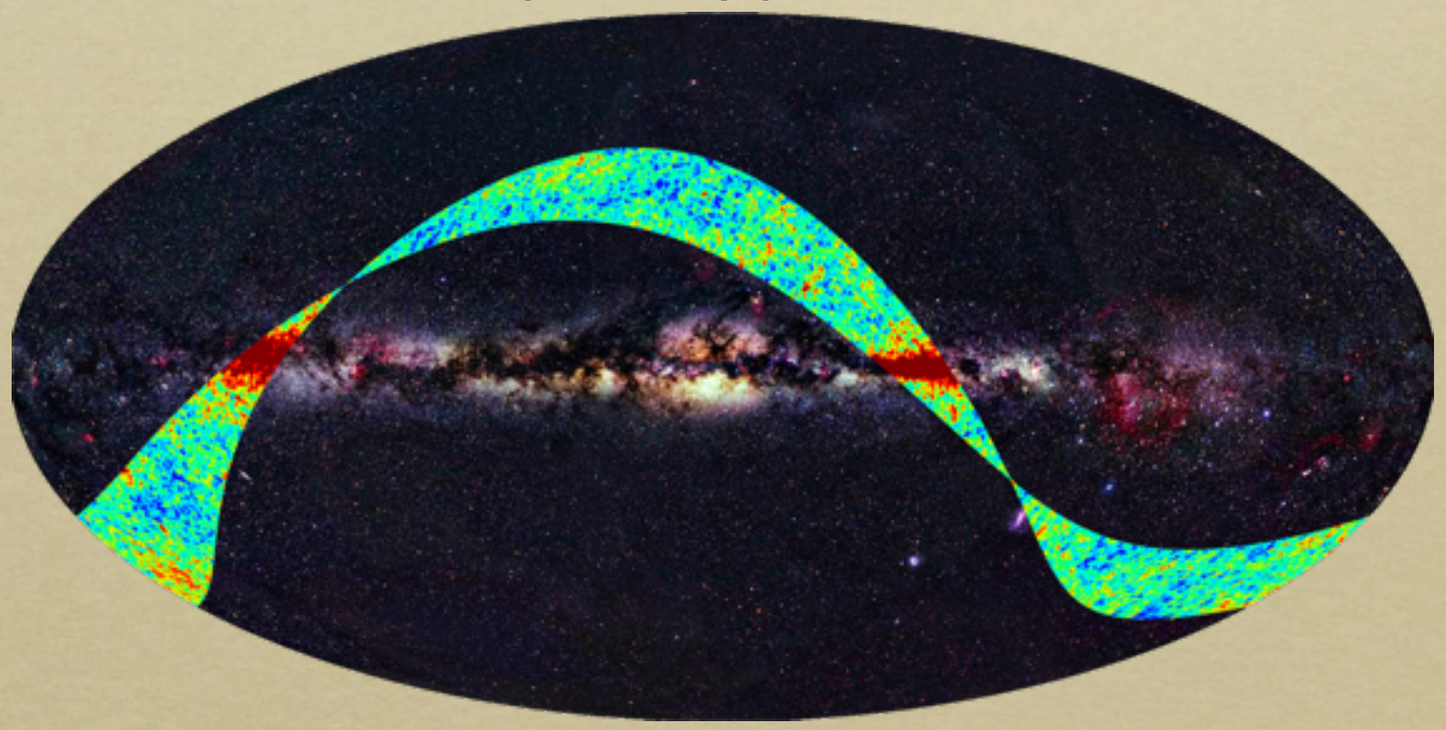
First Light Survey press release



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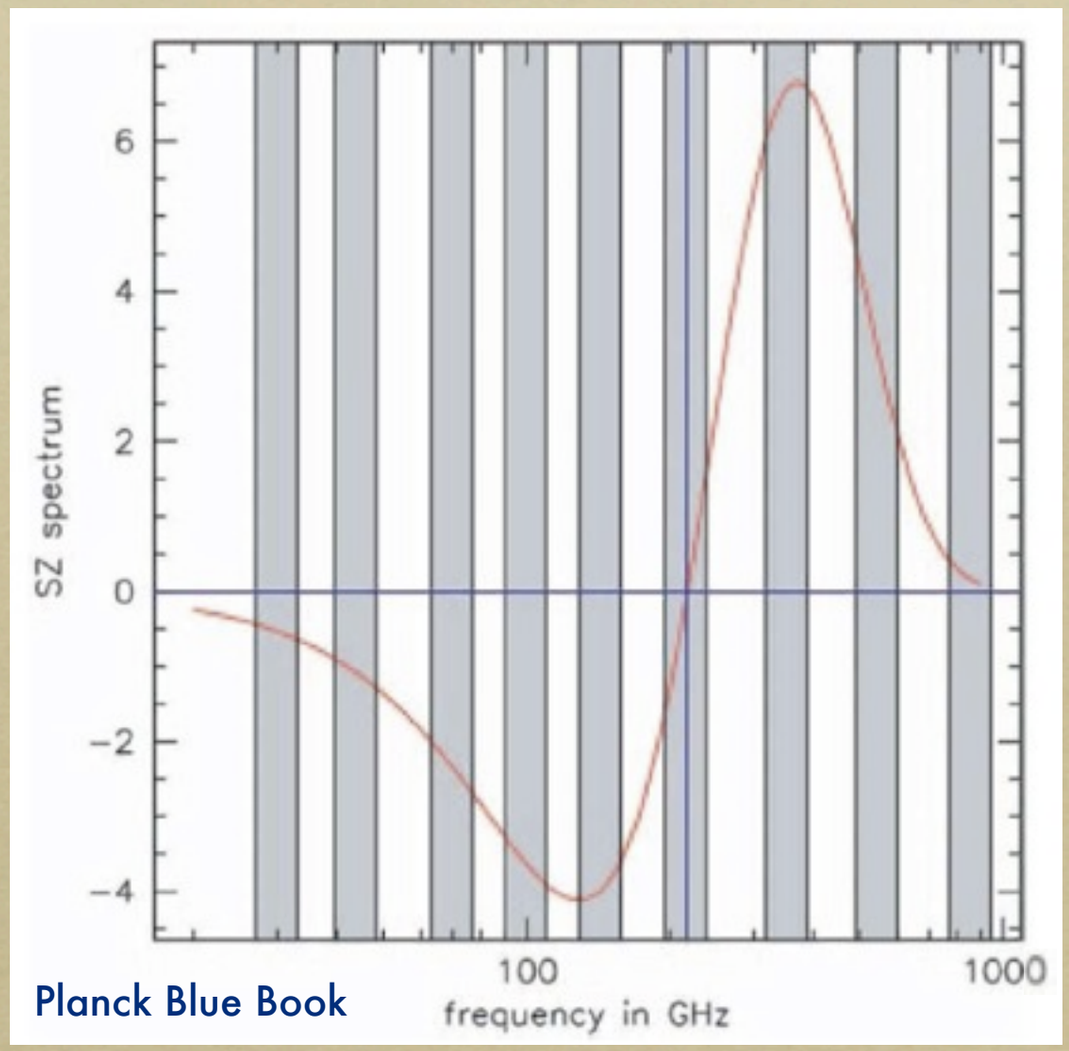
The Planck mission

SZ observations

- 9 frequency bands giving a good spectral coverage of the SZ spectrum
- Volume & depth
  - massive clusters up to z ~ 1
- Many clusters marginally resolved
  - selection function depends on cluster profile
  - photometry depends on source profile (precision on the size)



Planck Blue Book

The Planck mission

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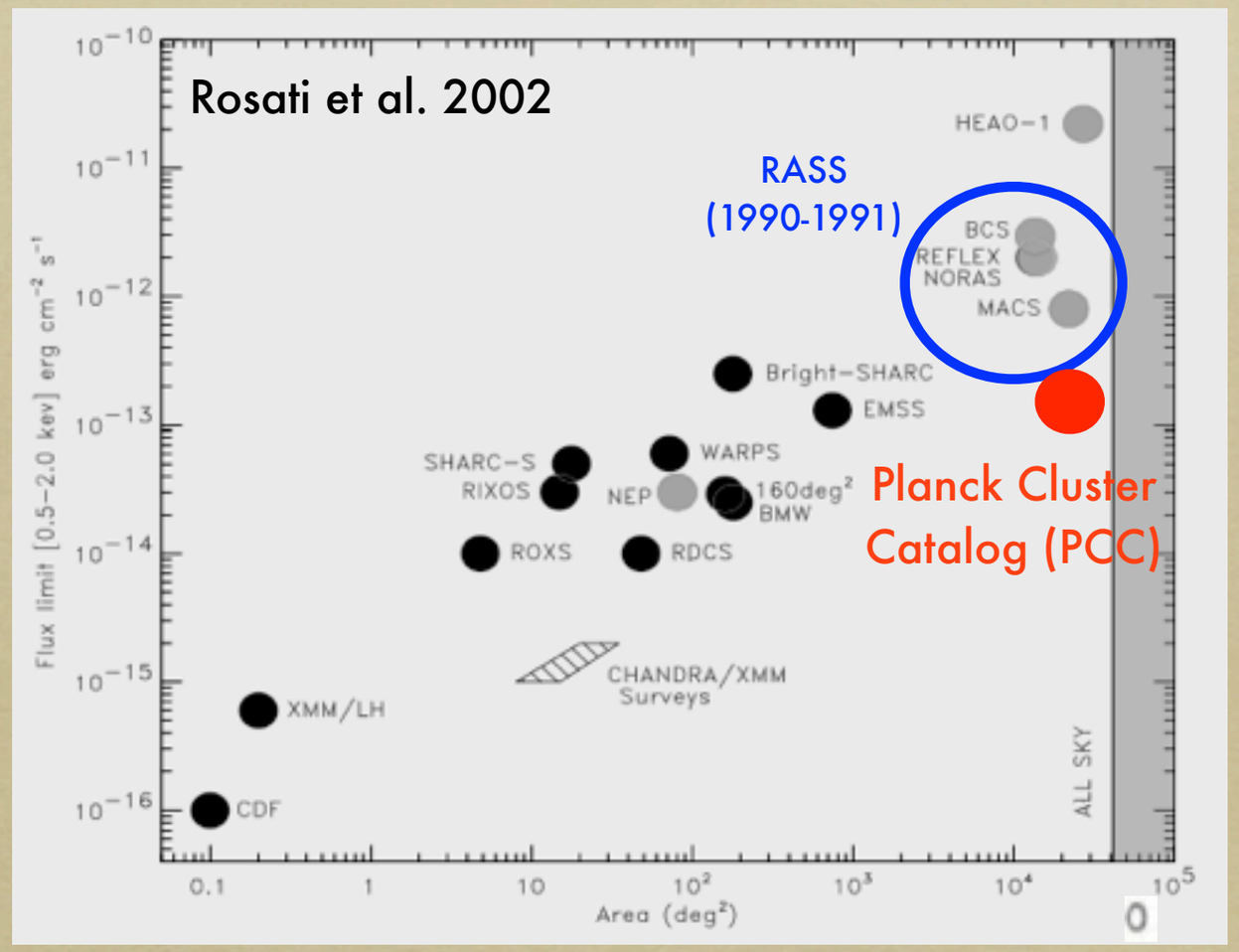
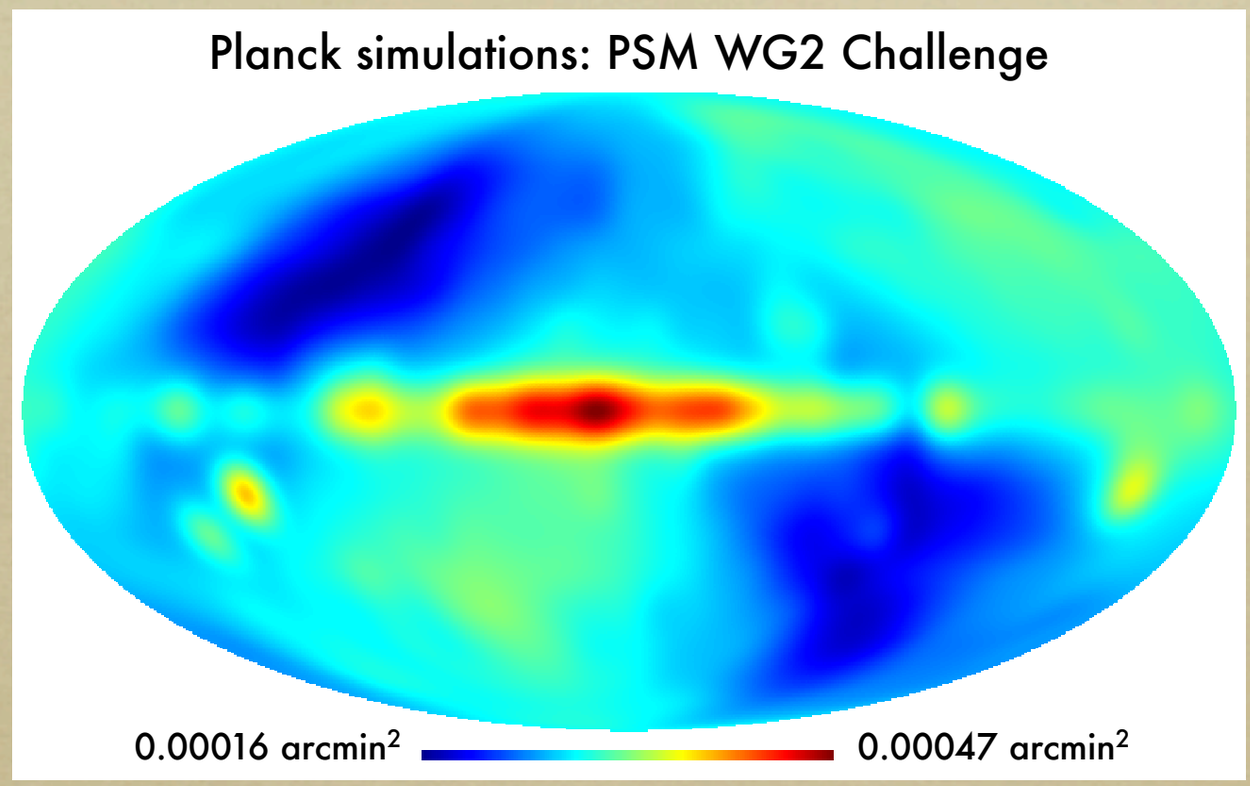


The Planck Cluster Catalog

Expected properties

- Multi-Matched Filter (Melin et al. 2006)
- Planck Sky Model (PSM) (Delabrouille et al.)
- WMAP-5 cosmology (Dunkley et al. 2008)
- Universal pressure profile (Arnaud et al. 2009)
- Self-similar scaling in mass and redshift: $r < 5 \times r_{500}$
- Jenkins mass function
- Conversion from M_{500} to $M_{Jenkins}$

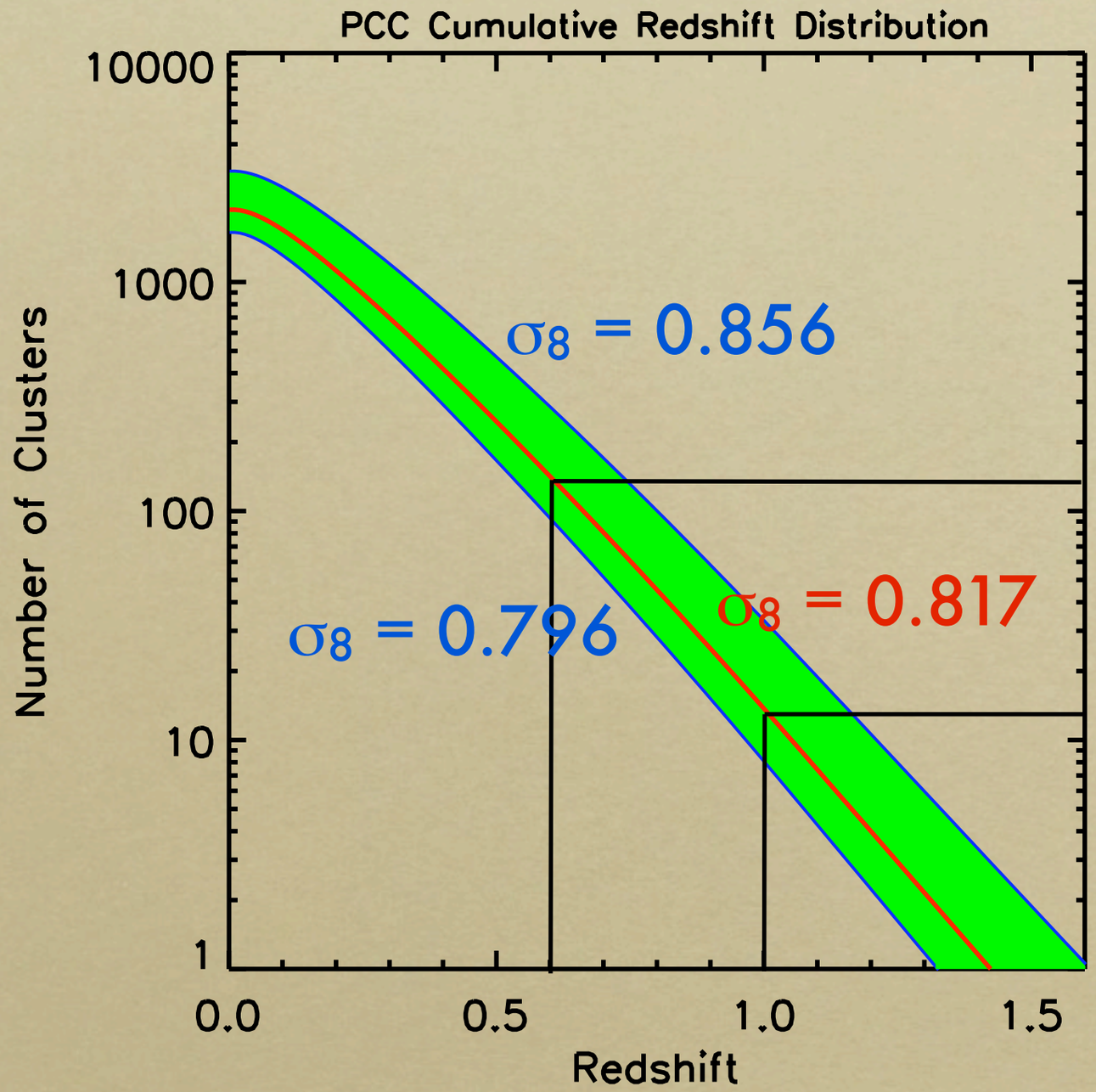
Filter fluctuations on smallest scales



Not flux limited

The Planck Cluster Catalog

Expected properties



The Planck Cluster Catalog

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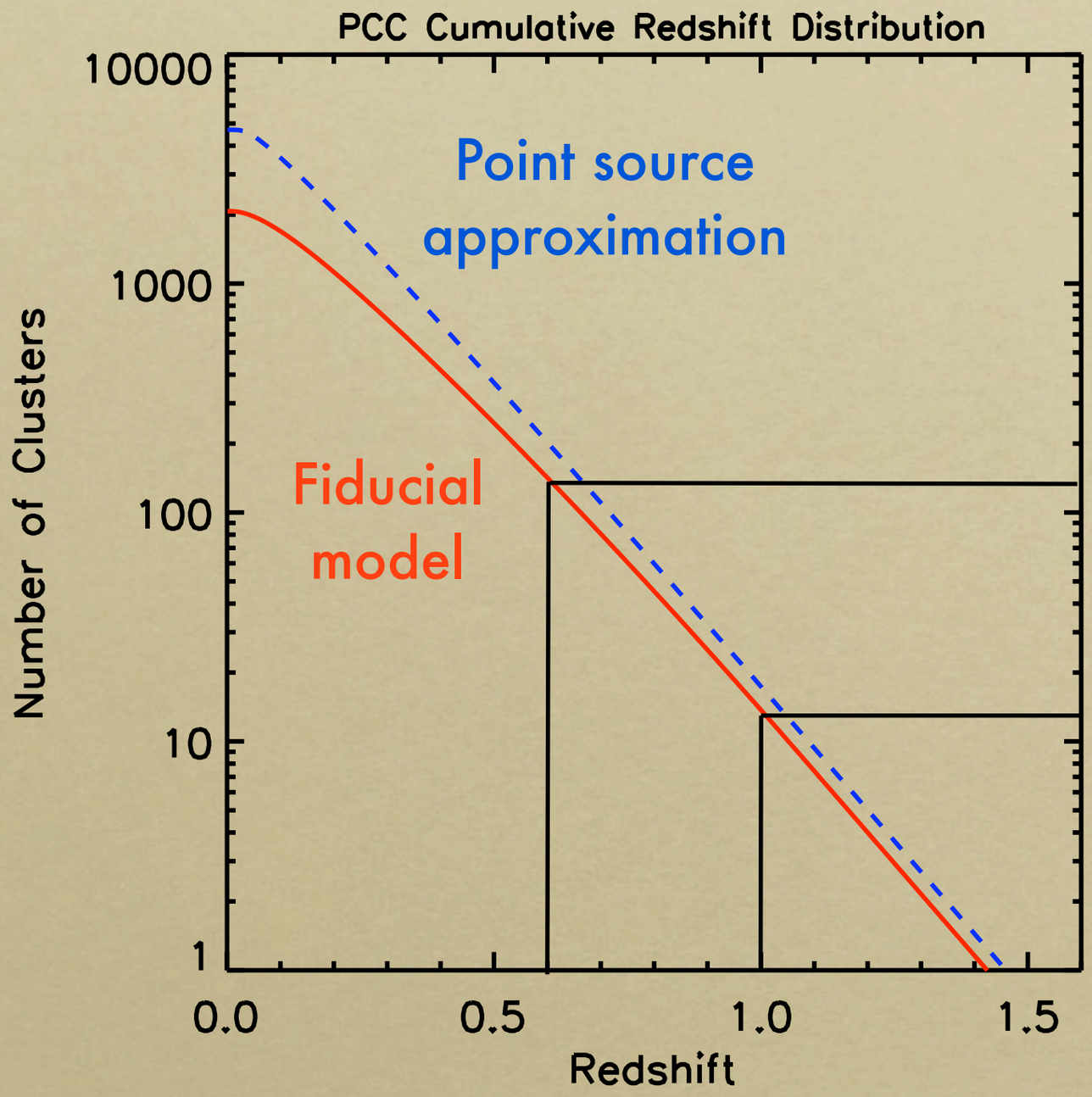


SZ/X-ray Properties

Model basis

- Scaling relations:
  - M_{500}-T relation (Arnaud et al. 2005, Vikhlinin et al. 2006)

$$M_{500} = 4.1 \times \left(\frac{T}{5\ \mathrm{keV}} \right)^{1.5} h^{-1}(z) \quad [10^{14} M_\odot]$$

  - L-M_{500} relation(s) (Pratt et al. 2008)

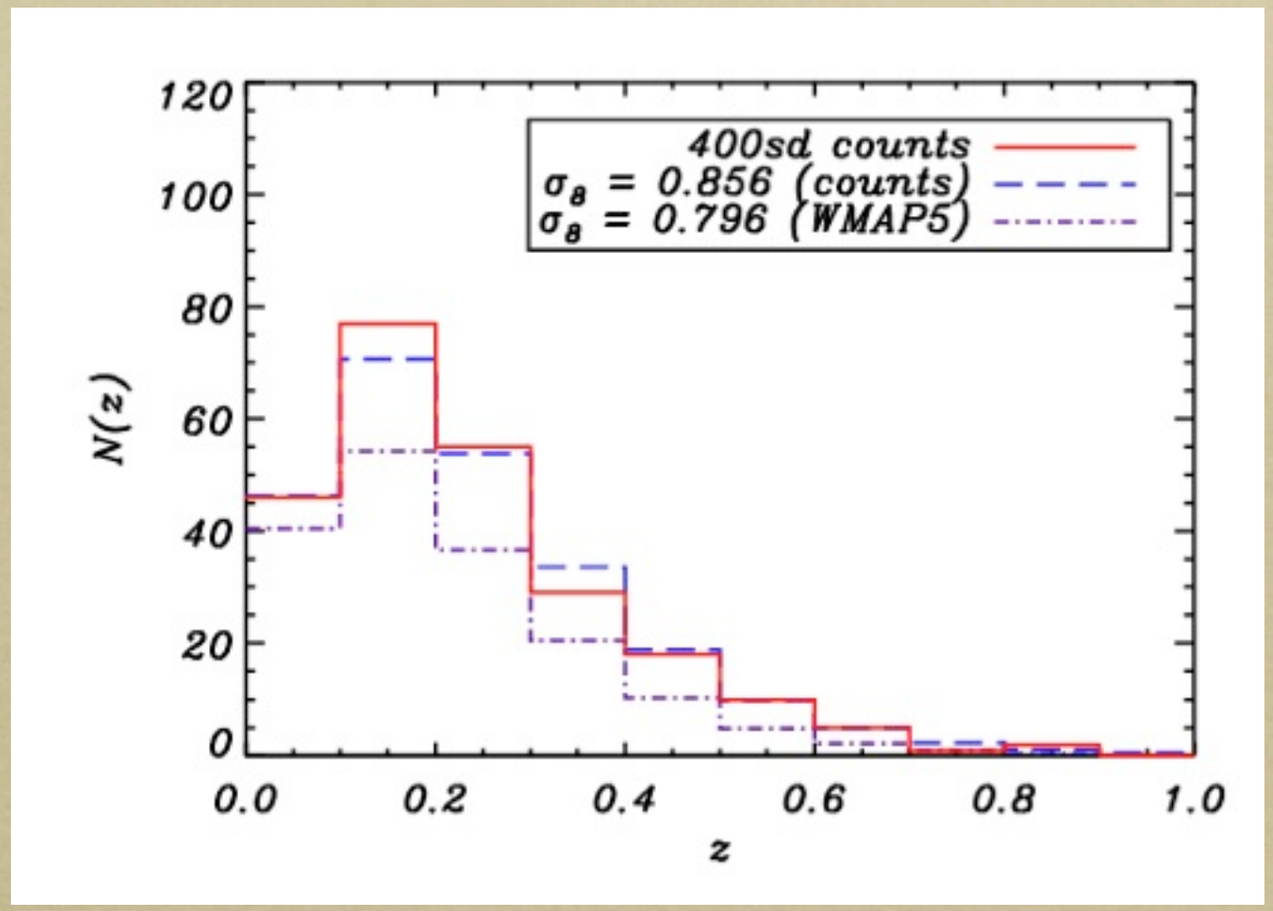
$$L_X = 0.38 \times \left(\frac{M_{500}}{2 \times 10^{14} M_\odot} \right)^{1.53} h^{7/3}(z) \quad [10^{44}\,\mathrm{ergs/s}]$$

- Mass function from Jenkins et al. 2001
- Mass conversion assuming NFW profile for dark matter with c = 4.3
- WMAP-5 cosmology (Dunkley et al. 2008), except for σ_8 which is determined from local counts (400sd)

SZ/X-ray Properties

Model validation

- σ_8 = 0.856±0.01, from 400sd (Burenin et al. 2007) consistent within 2σ with WMAP-5
- Validation on:
  - local and high-z XLFs (Mullis et al. 2004) well reproduced
  - REFLEX (Böhringer et al. 2004) redshift distributions



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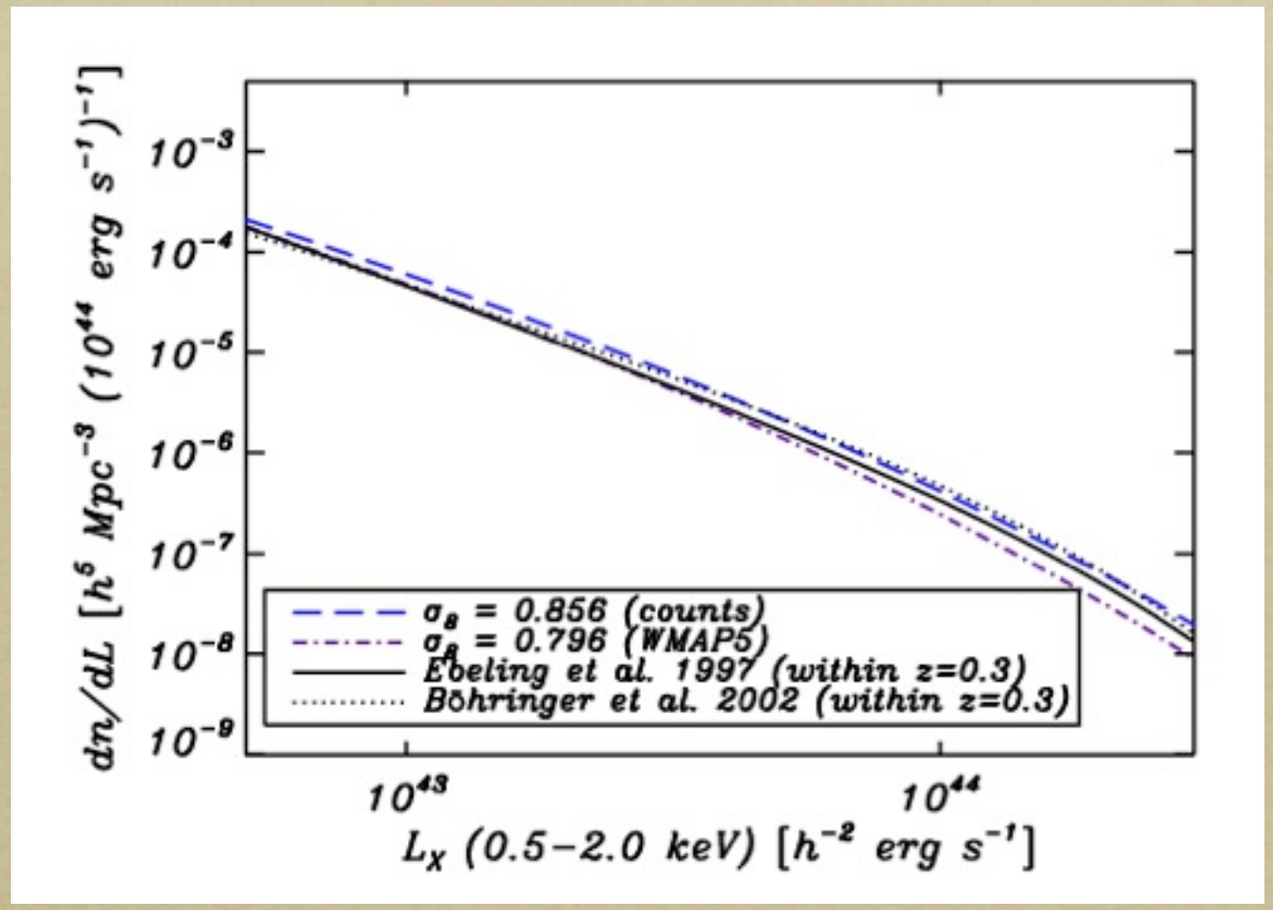

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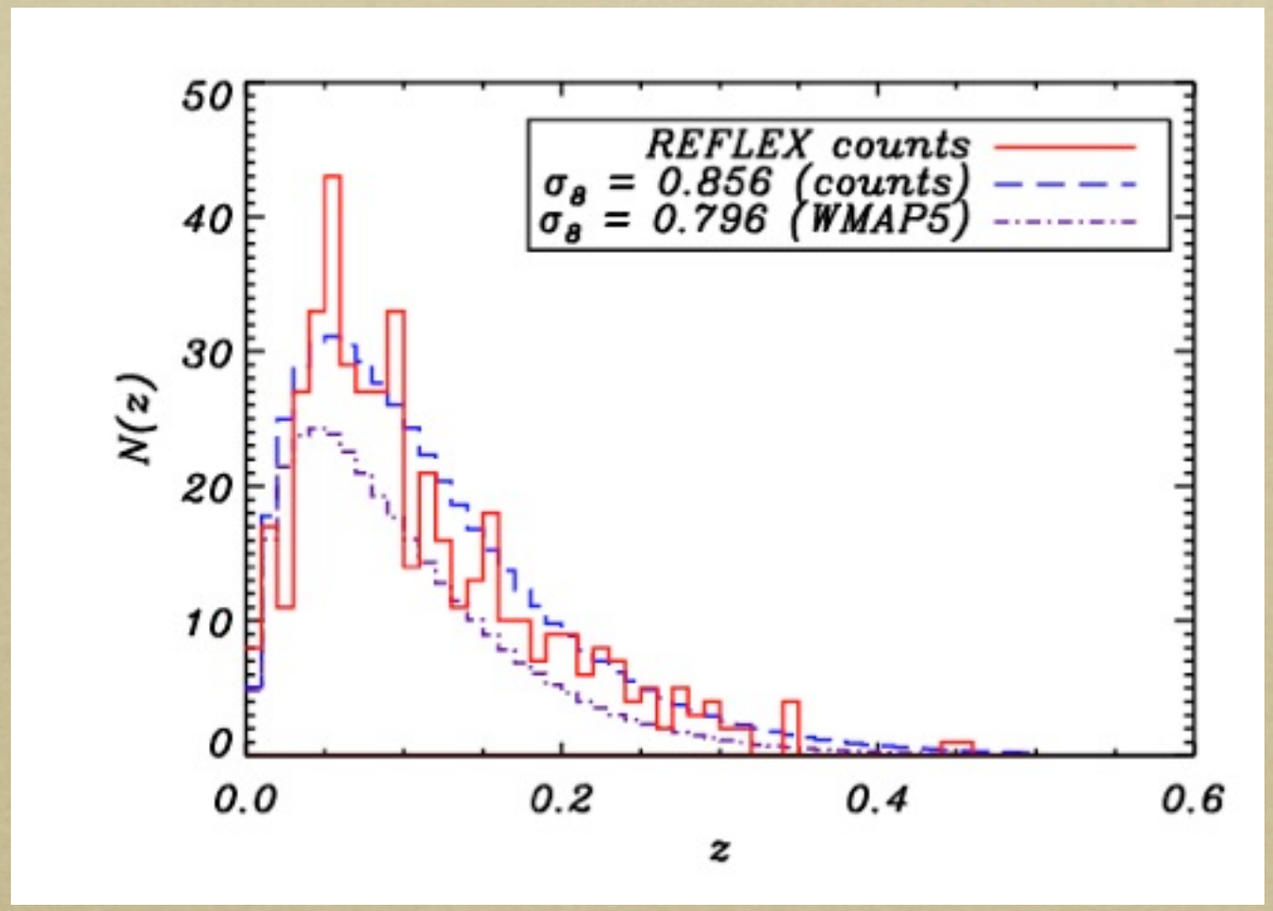
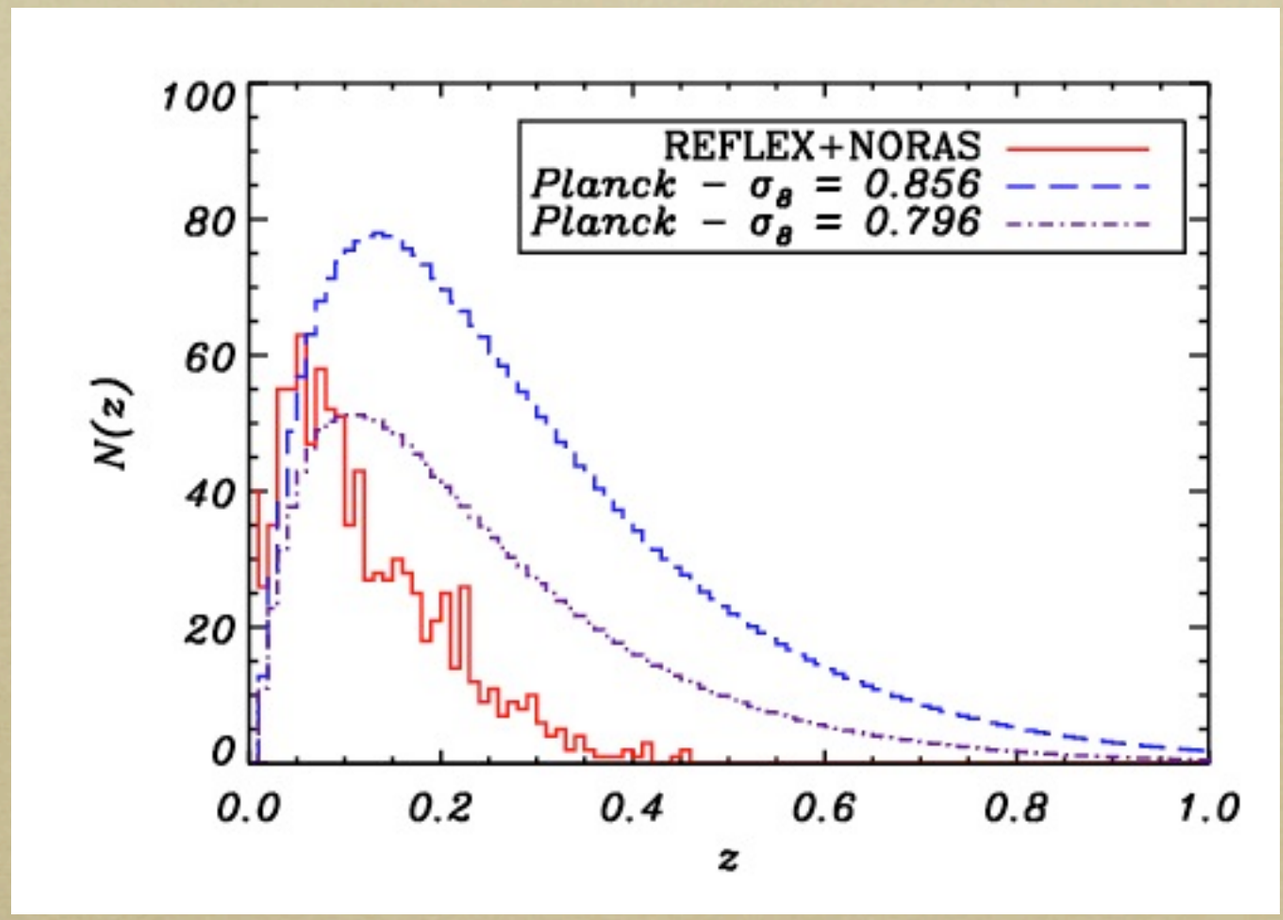


SZ/X-ray Properties

Comparison with existing surveys

- NORAS and REFLEX surveys (Böhringer et al. 2000, 2004):
  - ~ 30 000 deg^2
  - ~ 900 clusters
- Planck:
  - ~ 3000 (1600) clusters
  - bigger volume
  - efficient at high redshifts (flatter distribution)
  - New massive high-z clusters



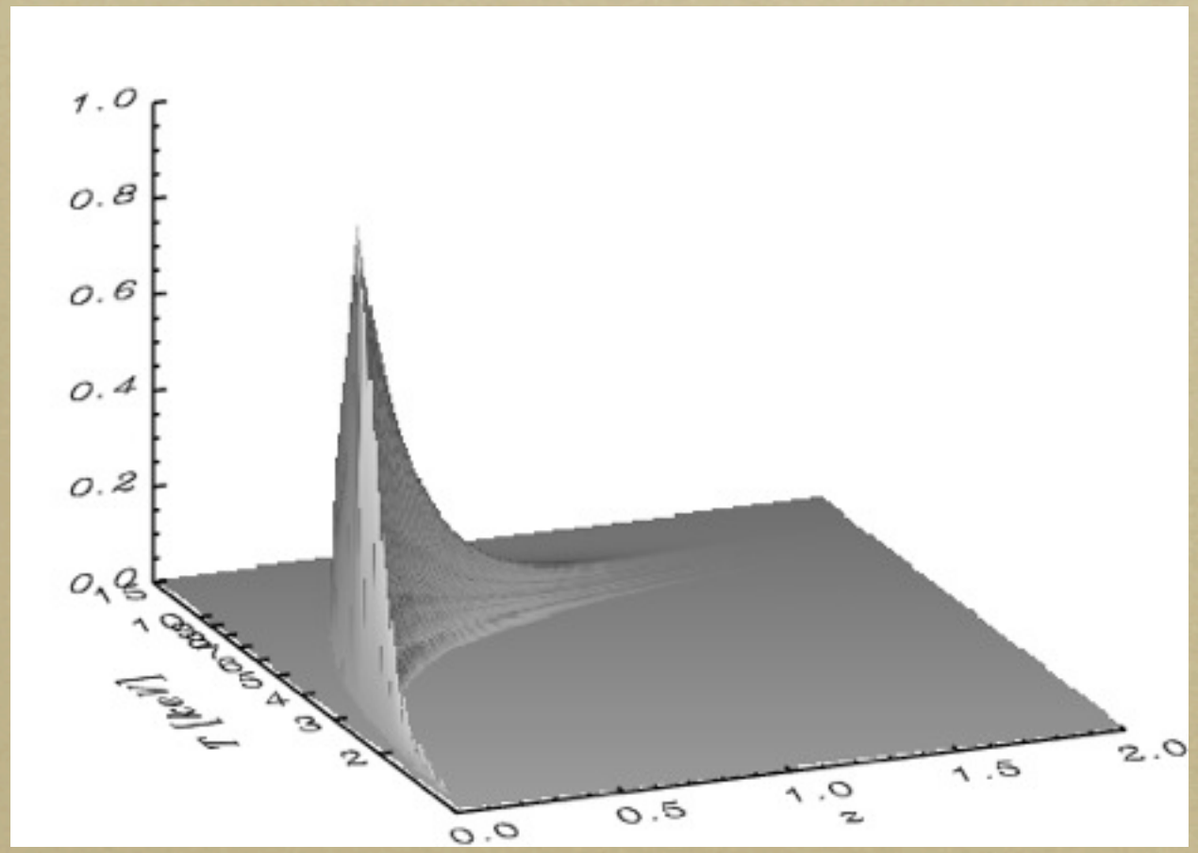
SZ/X-ray Properties
Comparison with existing surveys

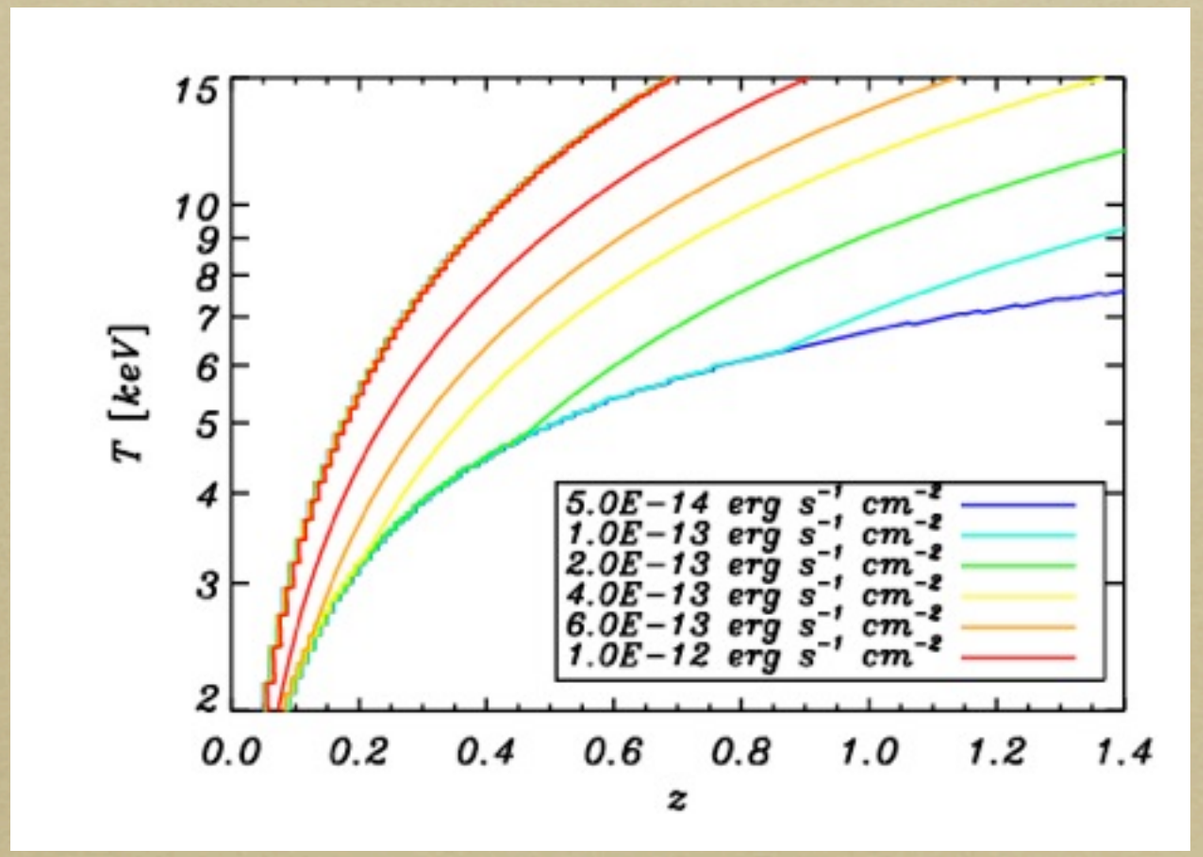
- Overlap between both catalogs:
  - 890 (570) clusters, *i.e.* 30% (34%) of the Planck catalog, with $f_x \geq 3.10^{-12}$ erg/s/cm^2
  - determination of scaling laws (Y_{SZ}-L_X, Y_{SZ}-Y_X, Y_{SZ}-T_X, Y_{SZ}-M…)
  - help in the determination of SZ fluxes when cluster size known from X-ray
- Clusters only in the RASS
  - some have high SZ fluxes, but are left undetected by Planck
  - determination of the Planck selection function via observations

SZ/X-ray Properties

Planck new clusters

Characteristics	Predicted number of clusters	
	$\sigma_8 = 0.796$	$\sigma_8 = 0.856$
All	1 672	3 005
New clusters	1 104	2 112
$z \geqslant 0.6$	95	278
$0.8 \leqslant z < 1.0$	20	65
$z \geqslant 1.0$	8	32



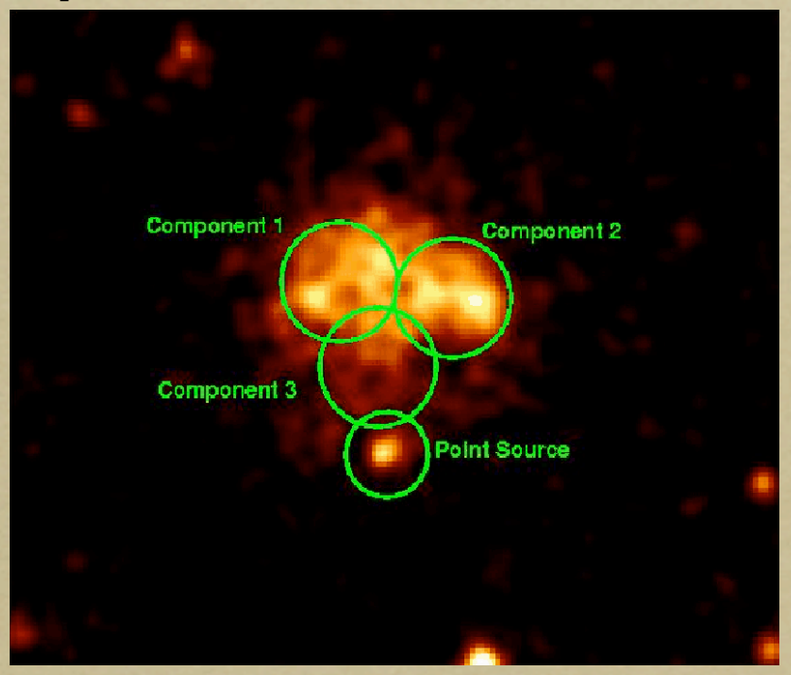


SZ/X-ray Properties

Targeted clusters

- Most massive (hottest) and distant clusters: more useful for cosmological studies
  - "hot" ≡ T ≥ 6keV; "distant" ≡ z > 0.6
- Bright X-ray clusters
  - "bright" ≡ $f_{x\ (0.5\text{-}2\ keV)} \geq 10^{-13}$ erg s^{-1} cm^{-2}
  - T estimated with 10% error with exposure time ≲ 55ks

- MS1054-0321 (Gioia et al. 2001):
  z = 0.847±0.05;
  T = 7.2±0.7 keV;
  $f_{x\ [0.5\text{-}2]keV} = 1.9 \pm 0.09 \times 10^{-13}$ erg s^{-1} cm^{-2}
  ⇨ exposure time: ~25 ks



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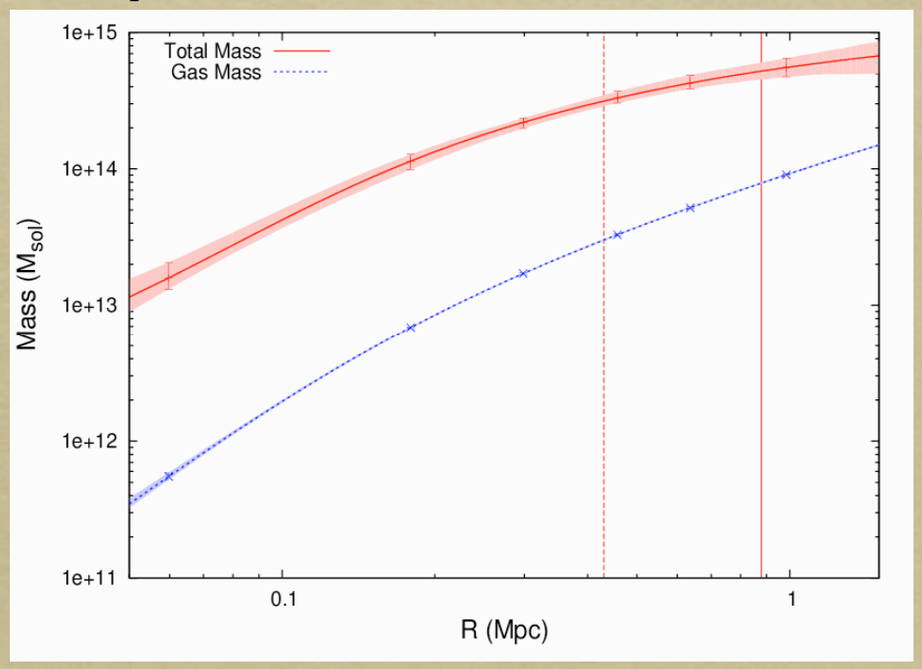
- ClJ1226.9+3332 (Maughan et al. 2007):
  z = 0.89±0.05;
  T = 10.4±0.6 keV;
  $f_{x\ [0.5\text{-}2]keV} = 3\times10^{-13}$ erg s^{-1} cm^{-2}
  $M_{500} = 5.2\pm1.0\times10^{14}M_{\odot}$
  ⇨ exposure time: ~70 ks



SZ/X-ray Properties

More numbers

Characteristics	Predicted number of clusters	
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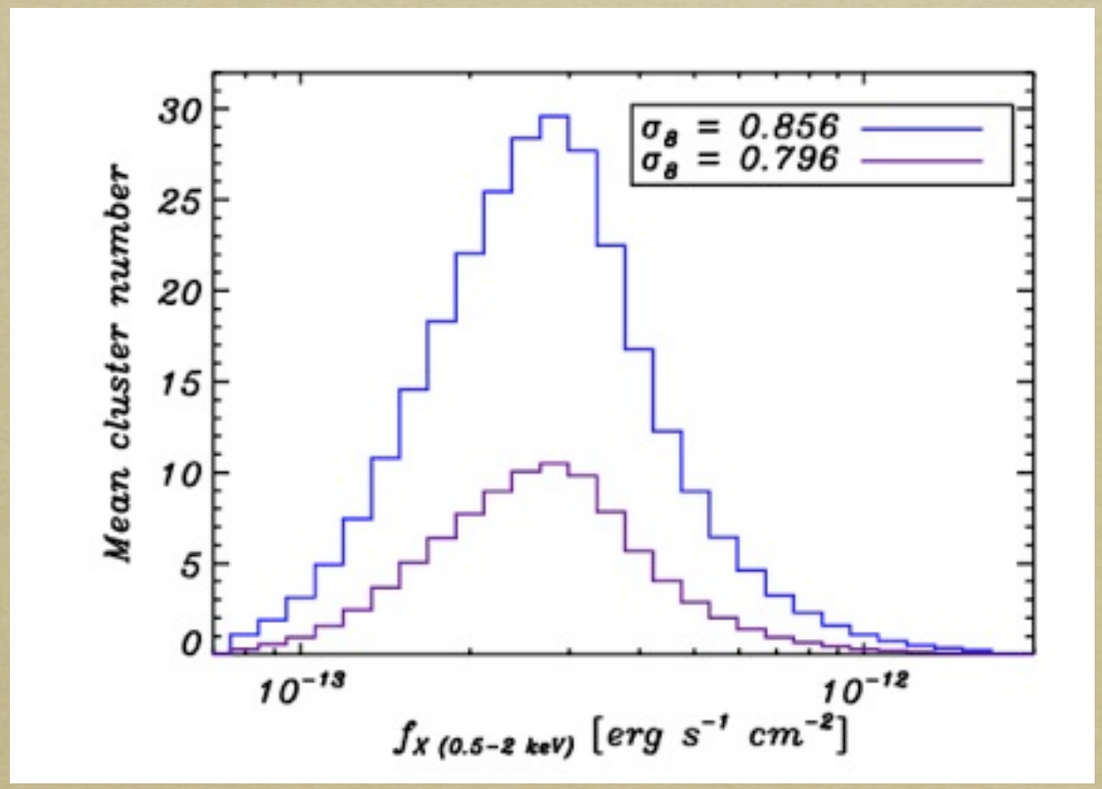
$z \geqslant 0.6$	95	278
$T \geqslant 6$ keV; $z \geqslant 0.6$	93	275
$T \geqslant 6$ keV; $z \geqslant 1.0$	8	32
$T \geqslant 6$ keV; $z \geqslant 0.6$; $f_x > 10^{-13}$ ergs/s/cm^2	92	271
$T \geqslant 6$ keV; $z \geqslant 1.0$; $f_x > 10^{-13}$ ergs/s/cm^2	7	29

- Most of the new distant clusters are hot
- … and bright in X-rays
- Significant increase compared to the number of known clusters



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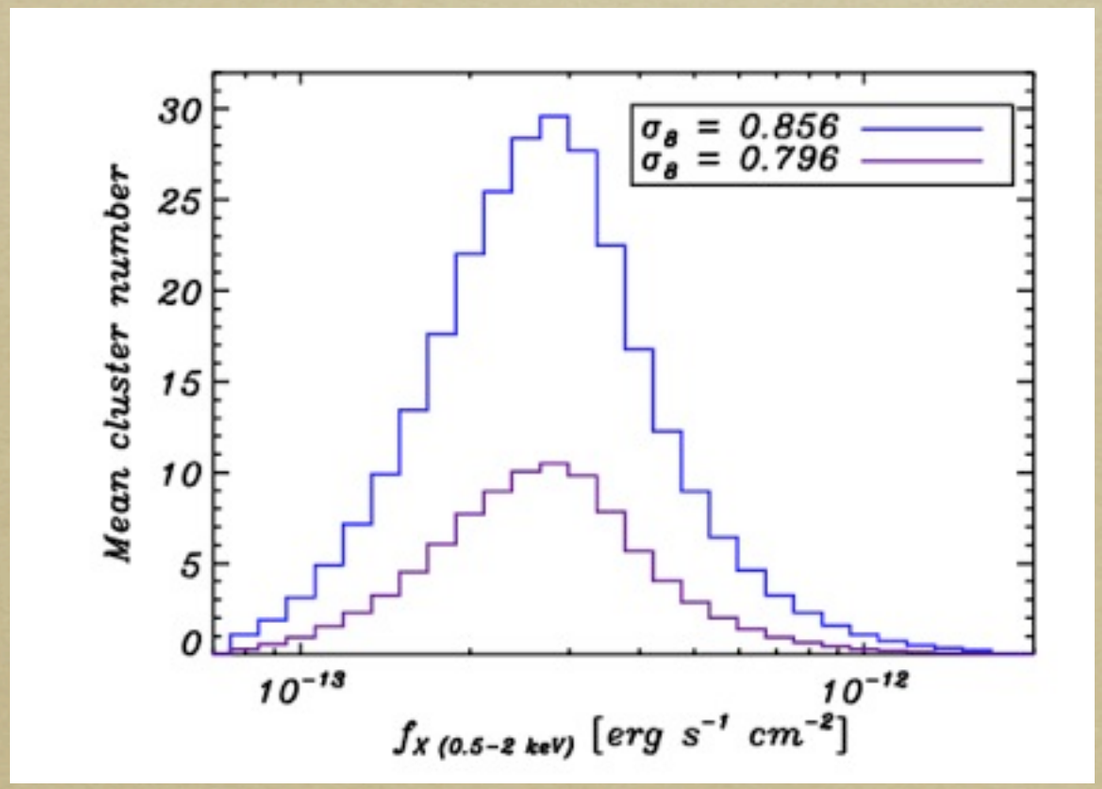

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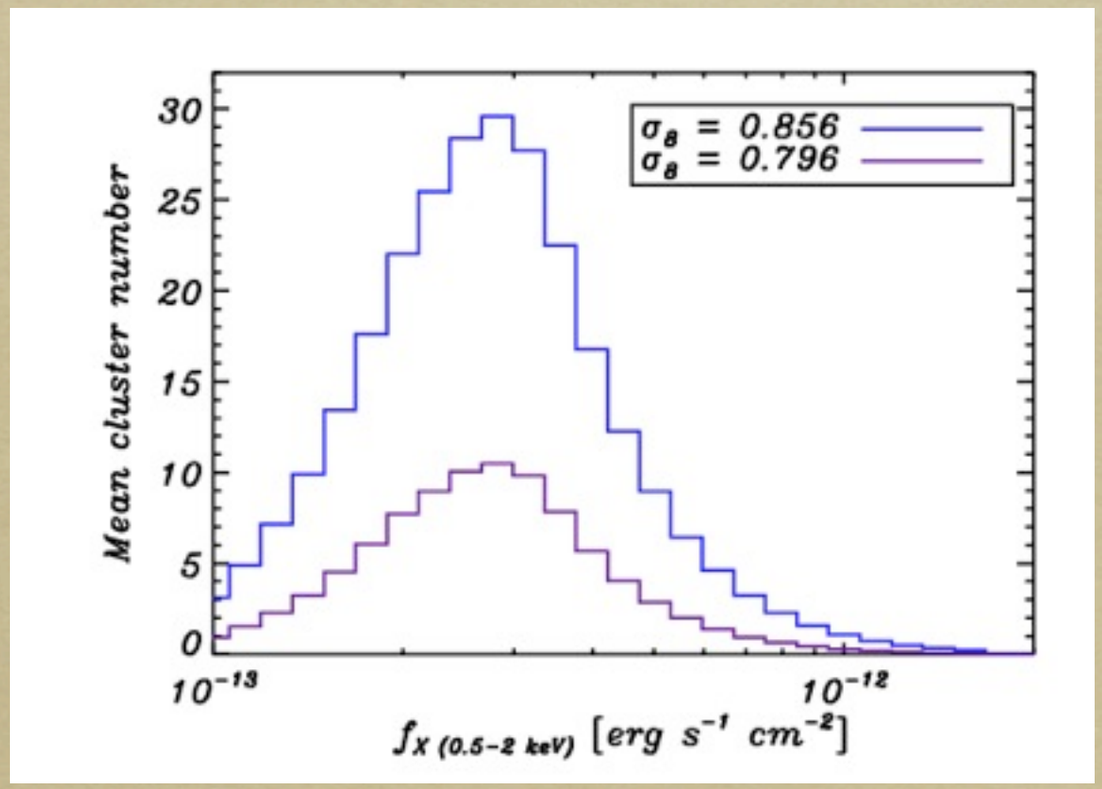
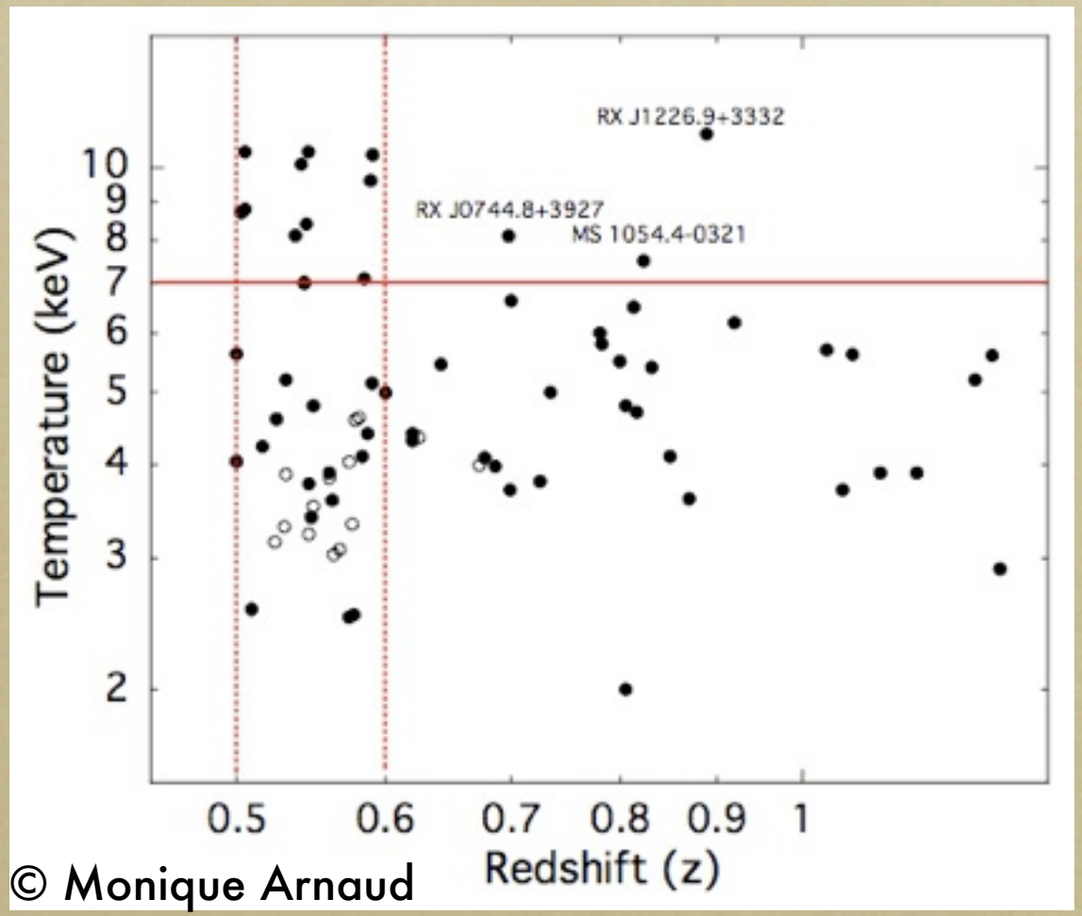


Significant increase

… compared to what?



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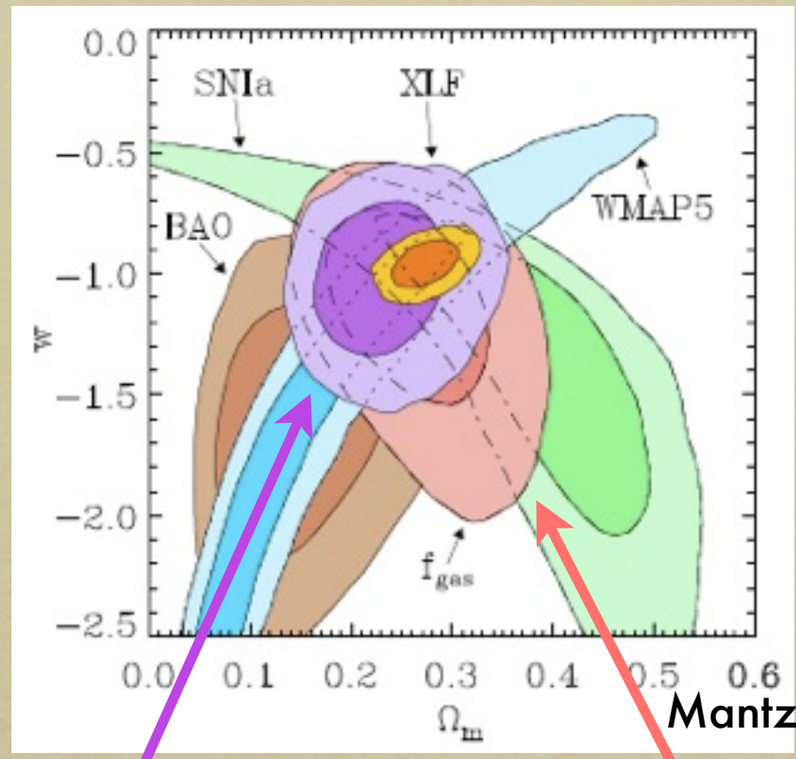
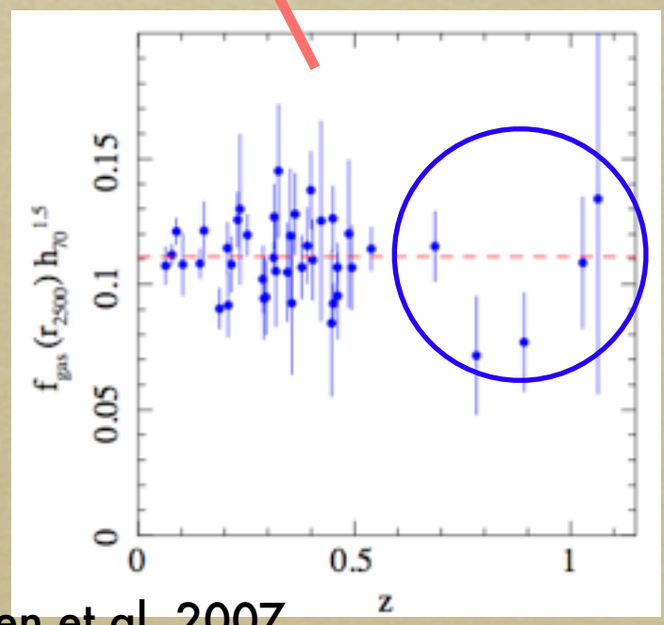
Includes EMSS, MACS, NORAS, REFLEX, SHARC, 160sd, 400sd, RDCS and WARPs



Mantz et al. 2009

238 clusters with $z < 0.5$



Allen et al. 2007

PCC SZ/X-ray Properties

Summary

- Planck has started its first full-sky survey of the CMB
- Planck will observe all of the most massive clusters, and all of the distant Planck clusters will be massive.
- Almost all of them are going to be bright enough in X-rays to be observed (with 10% error on T) in 55ks or less with X-ray satellites
- All this motivates the X-ray follow-up of the most relevant/easily identifiable of those clusters, in the frame of a few-Ms Very Large Project with XMM.