XXL

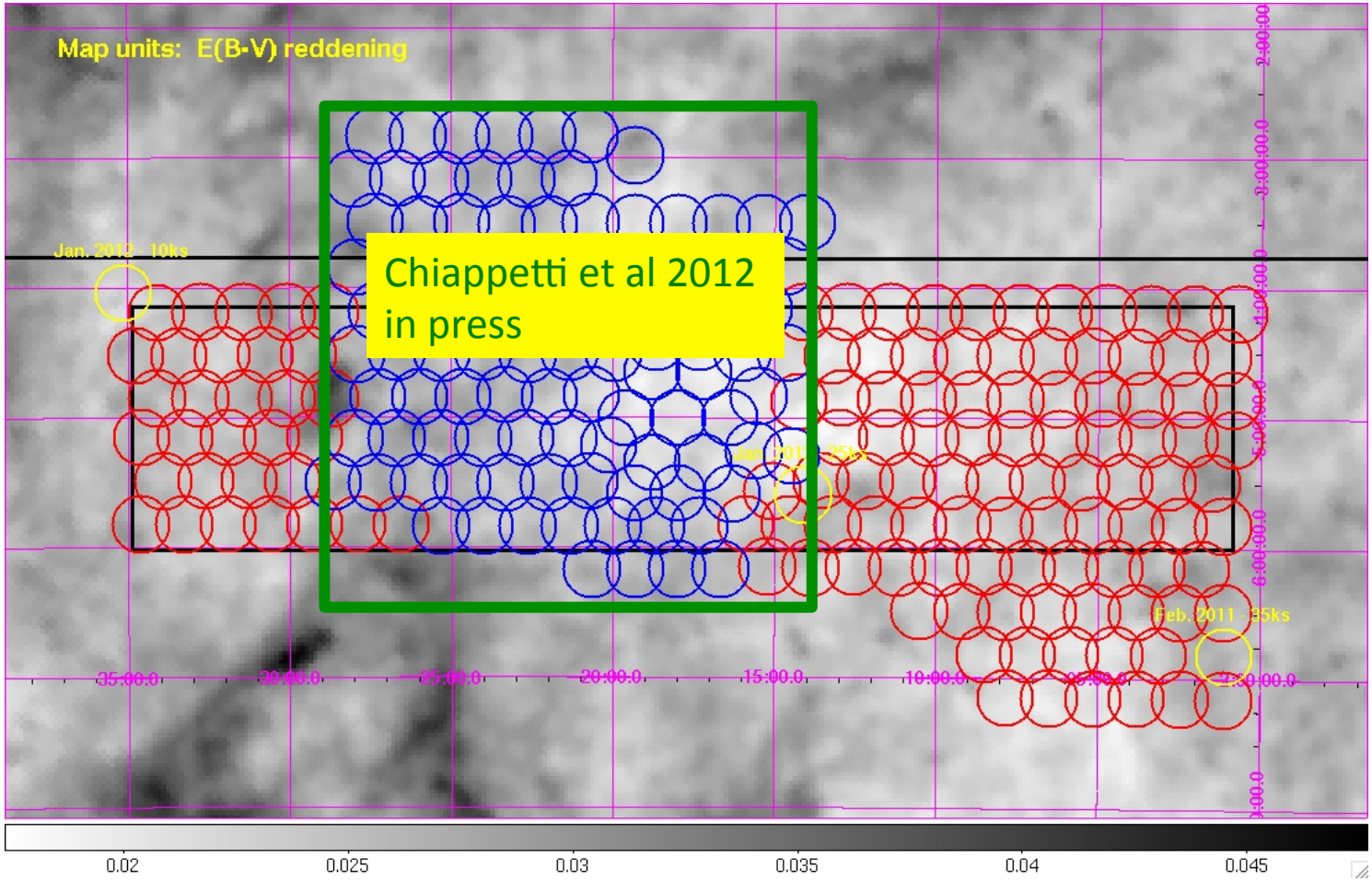
The ultimate XMM extragalactic survey

M. Pierre CEA Saclay

ESO Garching 2012

25 deg^2 in CFHTLS-W1 2h23 -5d00

(extension of the XMM-LSS field)

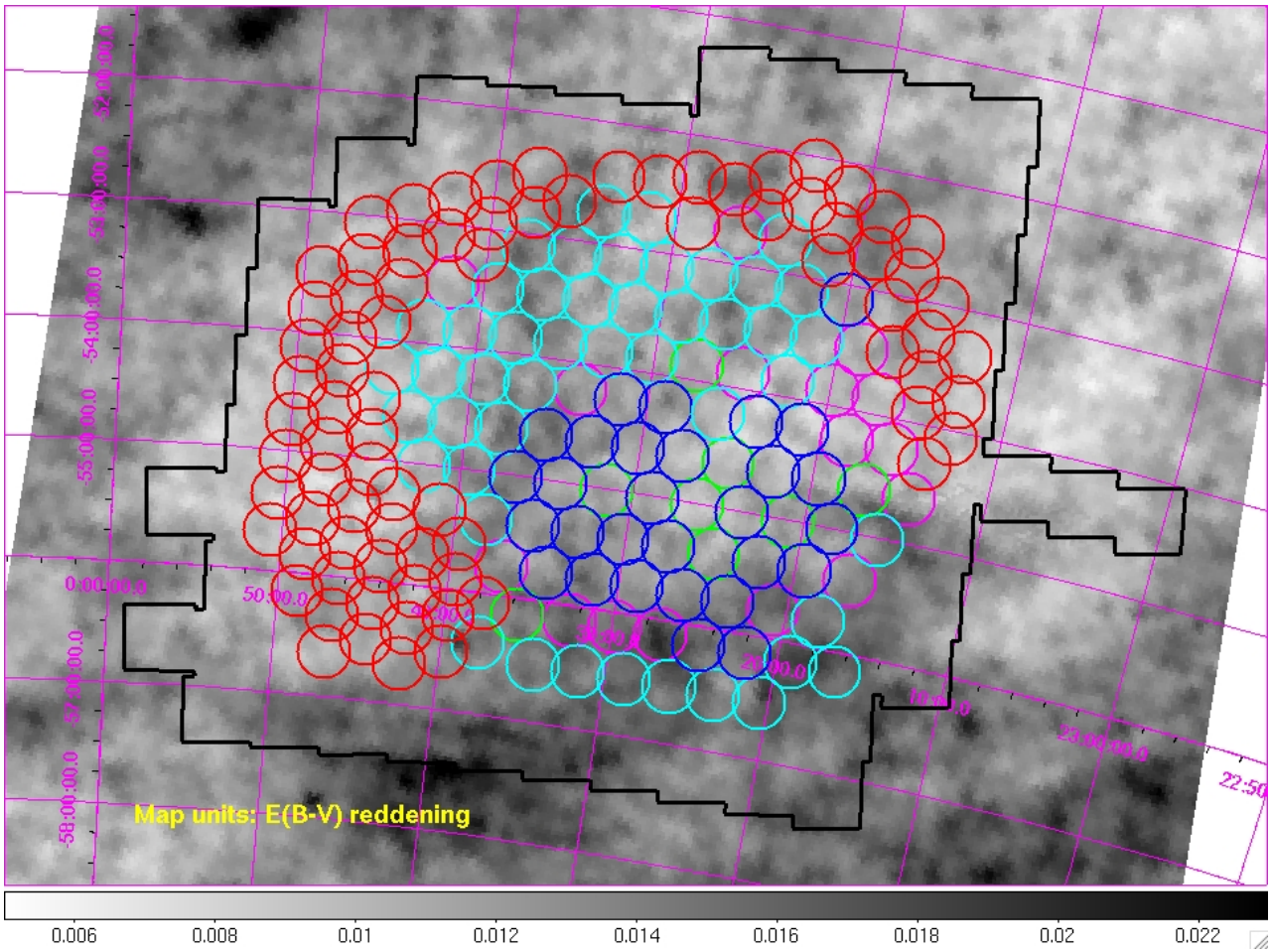


In red: the new observations (126)

$\Delta\alpha = \Delta\delta = 20'$ everywhere

25 deg^2 in BCS 23h30 -55d00

(extension of the XMM-BCS field)



In red: the new observations (80)

$\Delta\alpha = \Delta\delta = 20'$ ($\Delta\alpha = \Delta\delta = 23'$ in the initial central survey)

Outline

1. Lessons from the XMM-LSS survey

2 . An overview of XXL

3. A new method for analysing X-ray cluster surveys

1. Lessons from XMM-LSS

a pilot survey (2000-2009)

Life was simpler in the past…

THE *ROSAT* DEEP CLUSTER SURVEY: THE X-RAY LUMINOSITY FUNCTION OUT TO $z = 0.8$

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ABSTRACT

We present the X-ray luminosity function (XLF) of the *ROSAT* Deep Cluster Survey sample over the redshift range 0.05–0.8. Our results are derived from a complete flux-limited subsample of 70 galaxy clusters, representing the brightest half of the total sample, which have been spectroscopically identified down to the flux limit of 4×10^{-14} ergs m^{-2} s^{-1} (0.5–2.0 keV) and have been selected via a serendipitous search in *ROSAT* PSPC pointed observations. The redshift baseline is large enough that evolutionary effects can be studied within the sample. The local XLF ($z \leq 0.25$) is found to be in excellent agreement with previous determinations using *ROSAT* All-Sky Survey data. The XLF at higher redshifts, when combined with the deepest number counts constructed to date ($f > 2 \times 10^{-14}$ ergs cm^{-2} s^{-1}), reveals no significant evolution at least out to $z = 0.8$, over a luminosity range of 2×10^{42} to 3×10^{44} ergs s^{-1} in the 0.5–2 keV band. These findings extend the study of cluster evolution to the highest redshifts and the faintest fluxes probed so far in X-ray surveys. They complement and do not necessarily conflict with those of the *Einstein* Extended Medium-Sensitivity Survey, leaving open the possibility of negative evolution of the brightest end of the XLF at high redshifts.

Subject headings: cosmology: observations — galaxies: clusters: general — X-rays: general

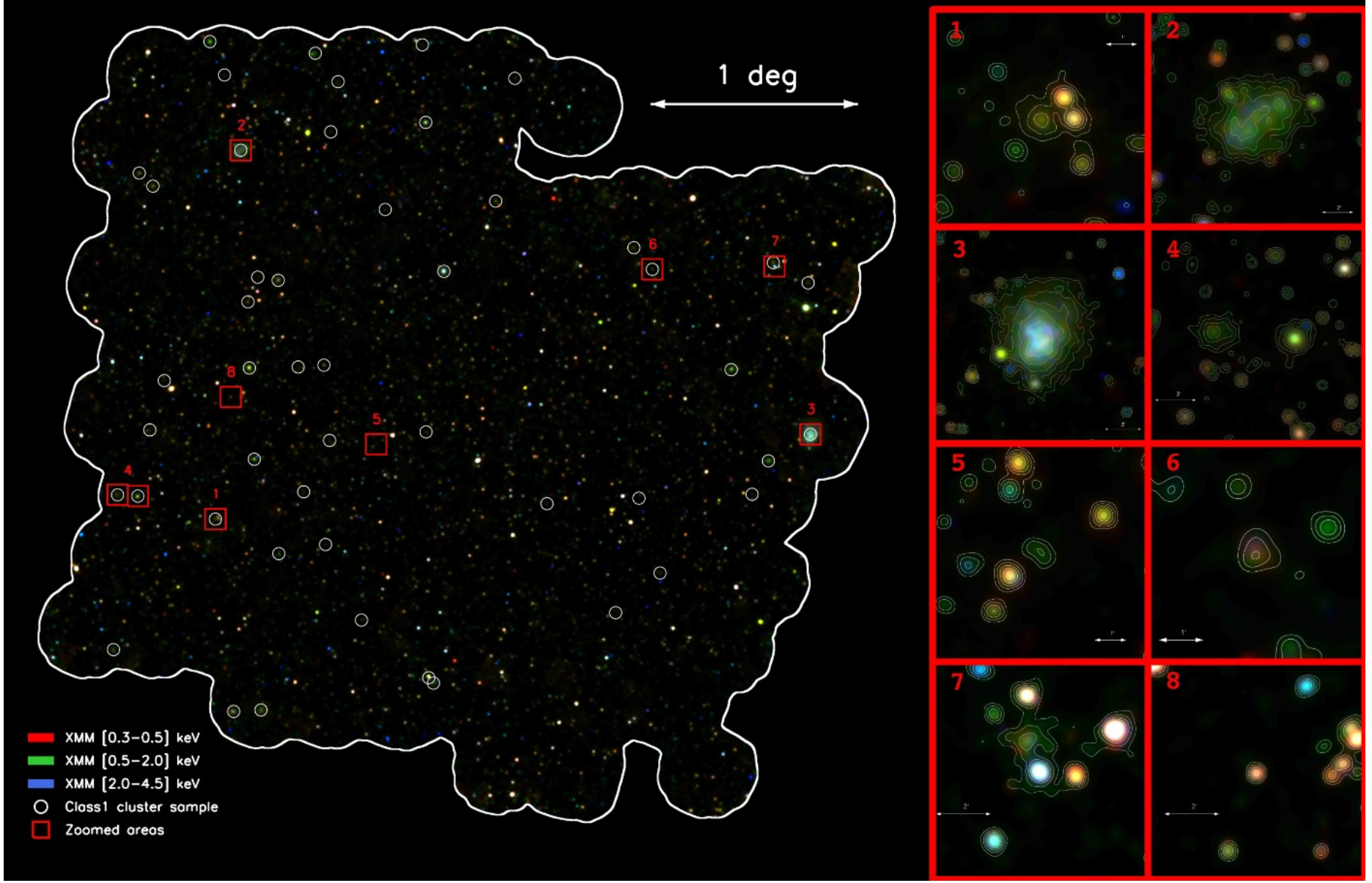
We adopt Ho= 50 qo = 1/2

1998 ApJ 492, L21 355 citations

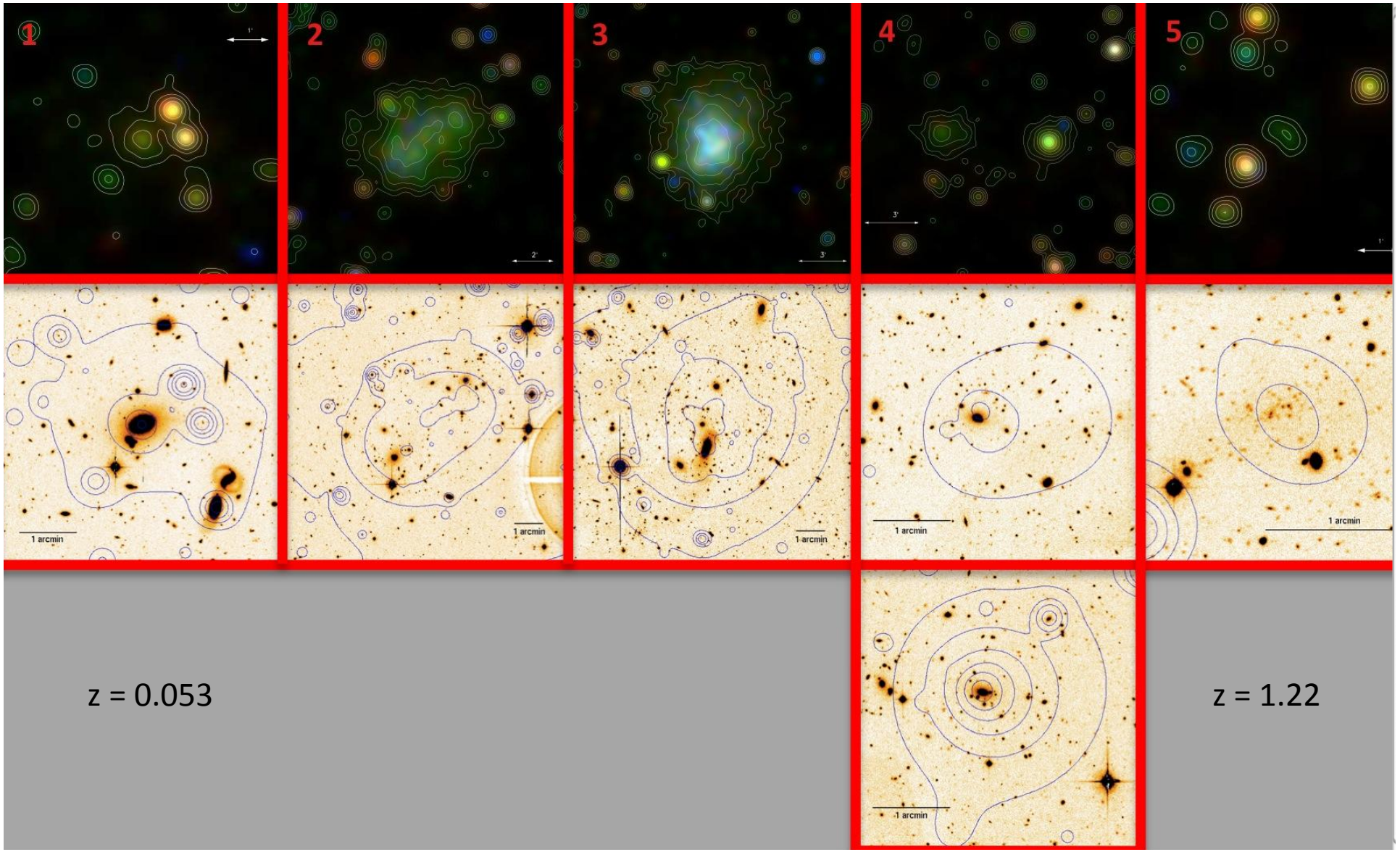
The XMM-LSS field

- 11 deg2 paved with 10-20 ks and including the SDS : 99 observations separated by 20'
- Optical coverage by the CFHTLS
- IRAC + MIPS survey from SWIRE
- Plus many others (VLA, GMRT, Integral, …)

The XMM-LSS survey



XMM-LSS clusters of galaxies and their optical counterpart (CFHTLS)



1) An unambiguous selection function

- For cosmological purposes, it is very necessary to have **a purely X-ray selected cluster sample**
  ➔ *ab initio* modeling

- This implies a 2D selection function

Pacaud et al 2006, 2007

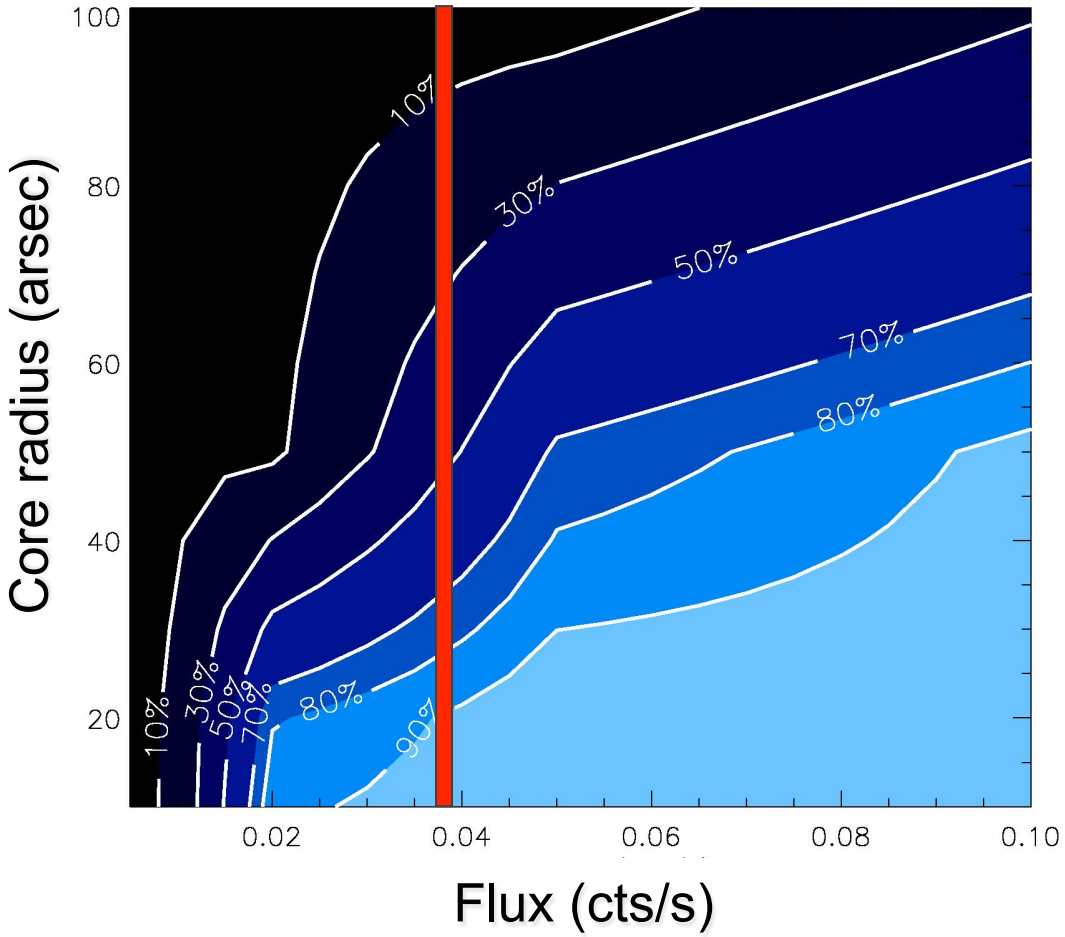
Not a flux limit !

Detection rates

Class 1 sample

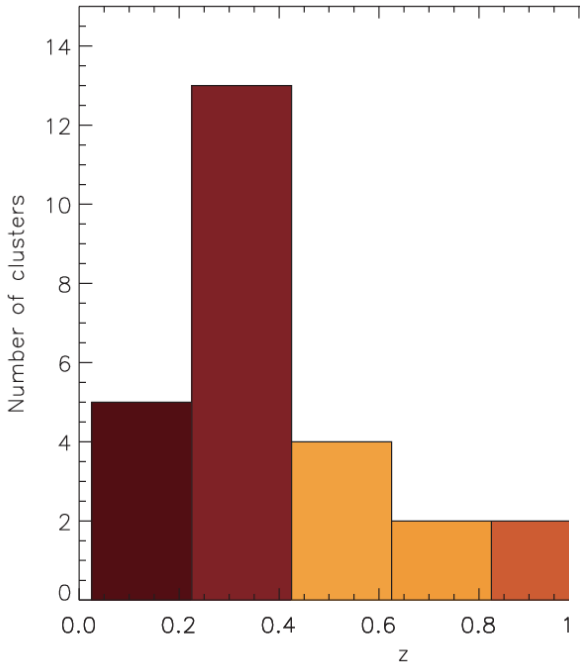
Not a flux limit !

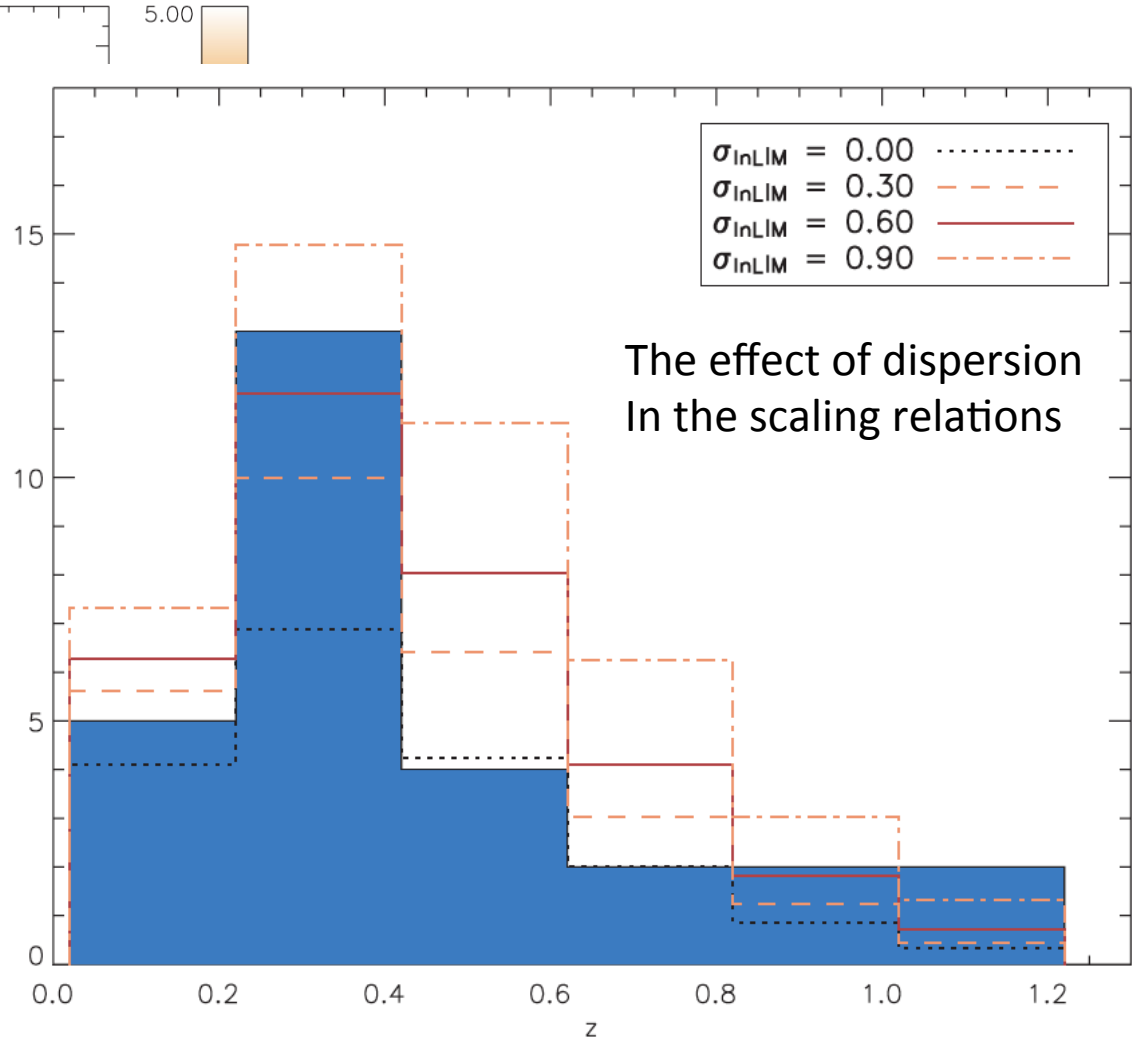
~ surface brightness limited



Pacaud et al 2006

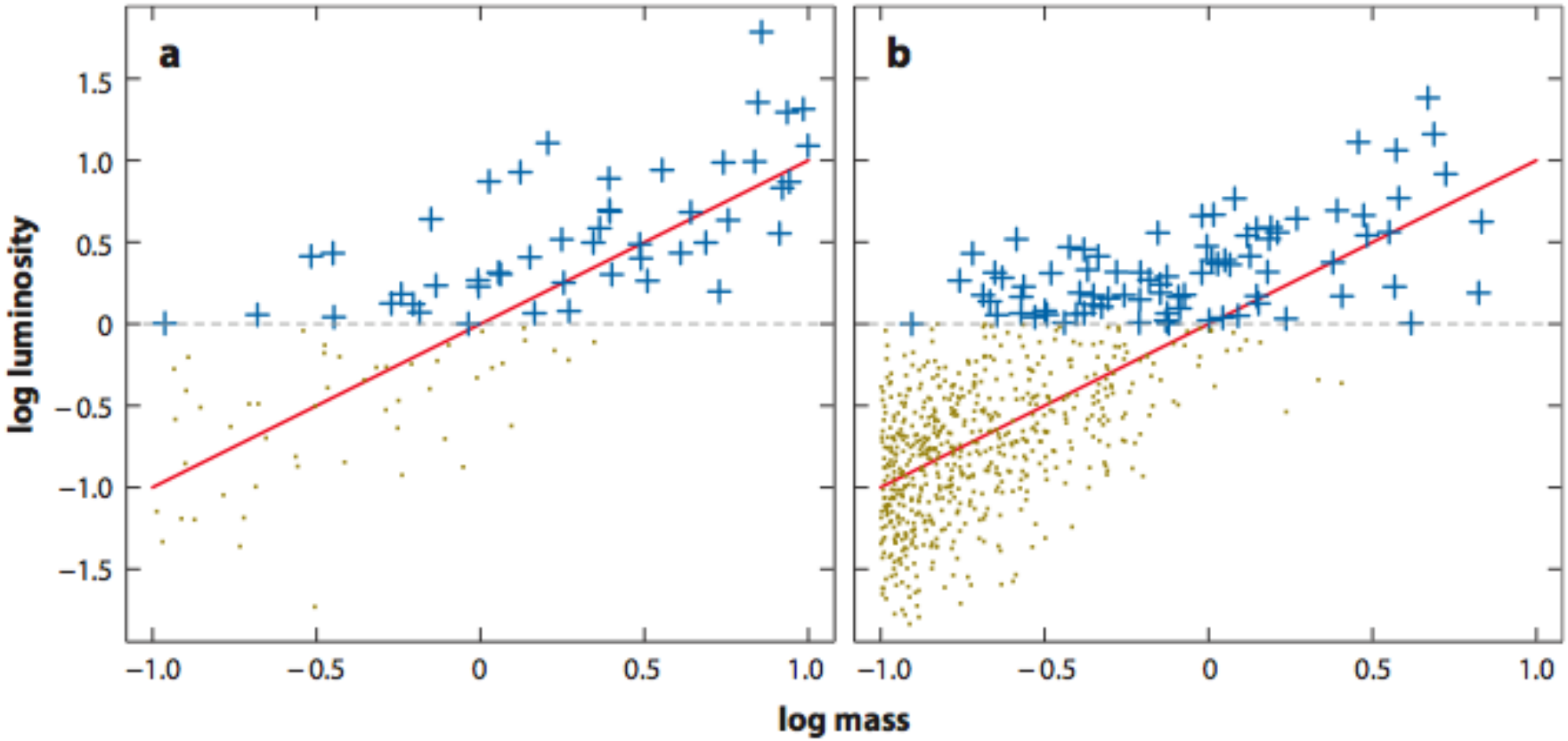
Results from the first 5 deg2





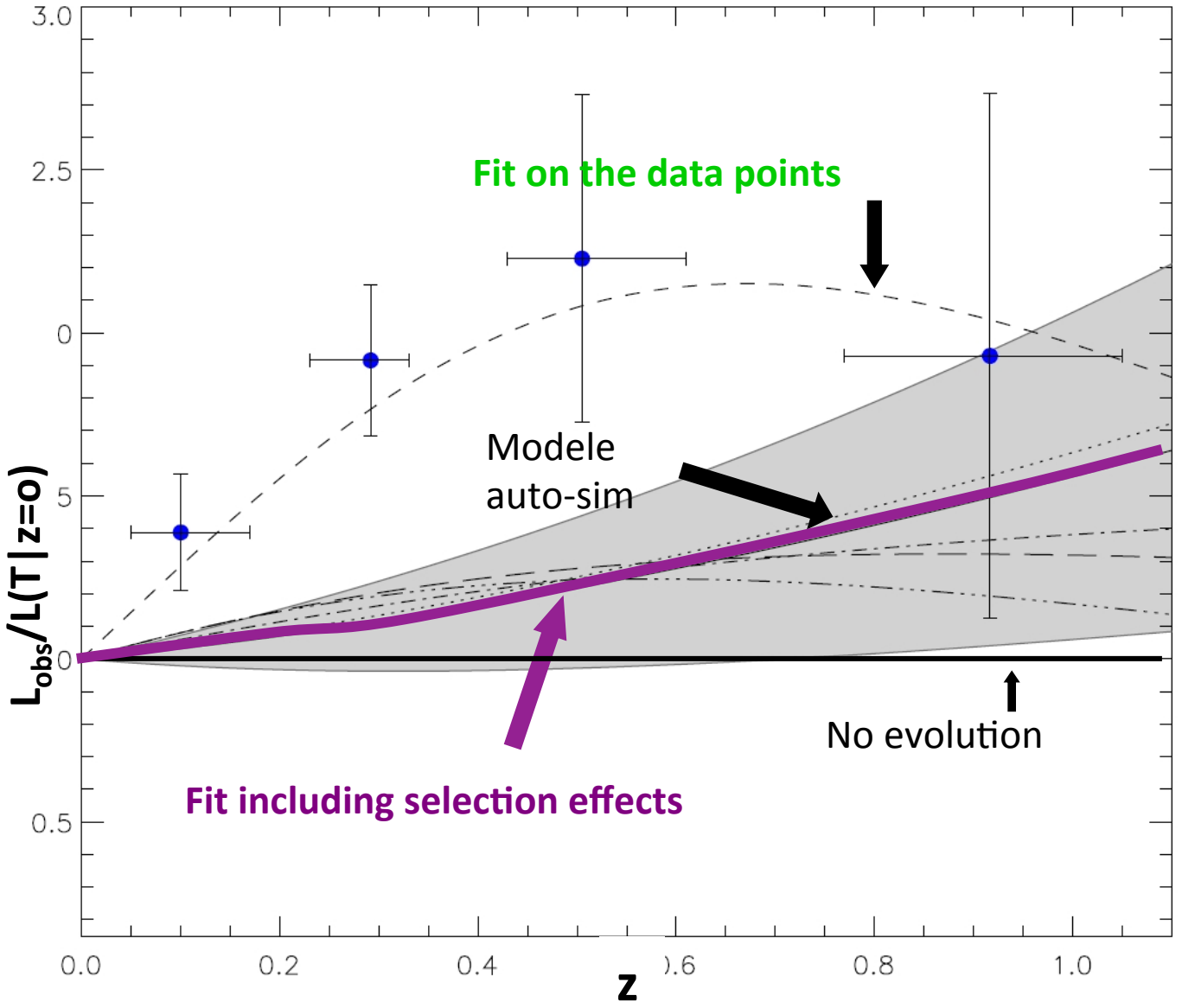
Lower fluxes ~ 10^{-14} erg/s/cm^2
In [0.5-2] keV

2) The dispersion **matters** a lot ….



Allen, Evrard, Mantz 2011

First attempt to self-consistenlty model **selection effects** in the scaling relations



Pacaud et al 2007

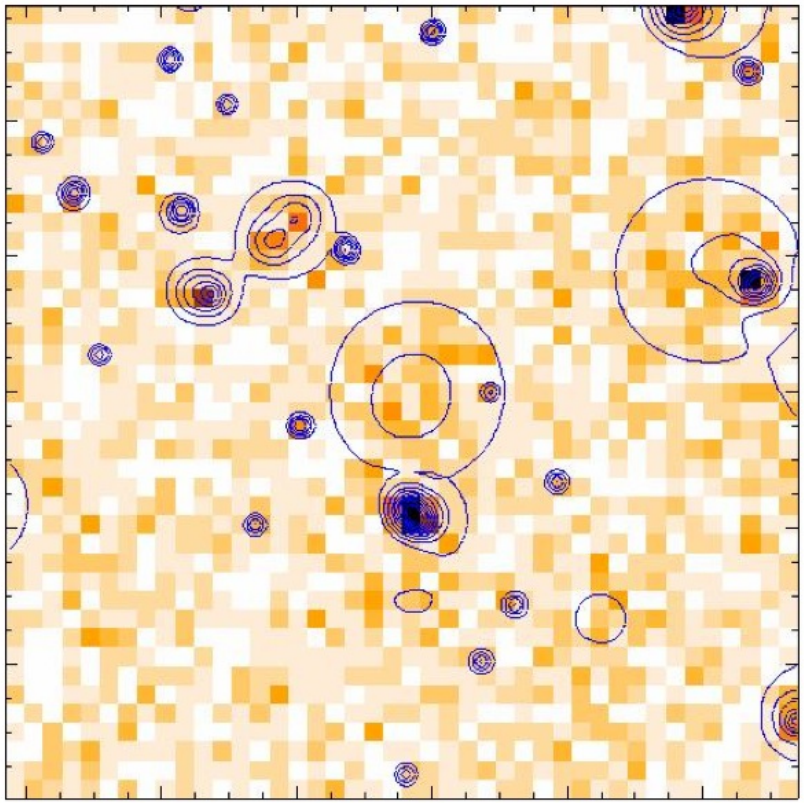
3) Distant clusters

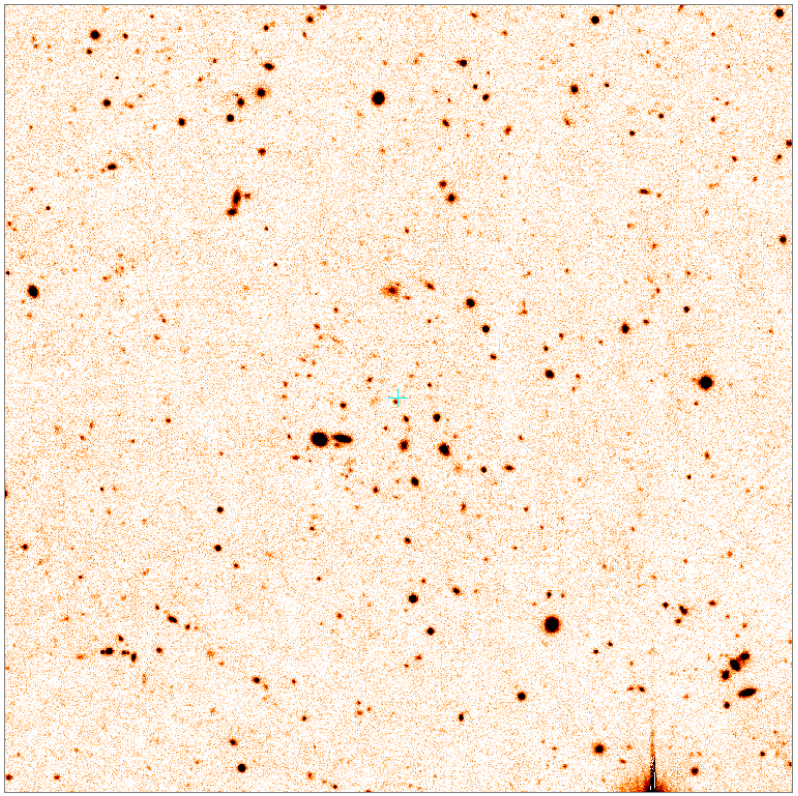
- 10 ks XMM are enough to detect a Coma cluster at z = 2.
- 1-2 C1 clusters per deg^2 beyond z>1

- Clusters at z>1.2 are readily identifiable
  - extented sources without counterpat in the I band
  - always have a counterpart in IRAC!

A distant candidate at z ~ 1.5

ID_1762





I 3.6 μm 4.5 μm

Ancillary data

- Having uniform coverage in u,g,r,i,z +
  3.5, 4.6 μm has proven extremely poverful
  - Cluster ID
  - Photo-z

- Optical spectroscopy (clusters <1) is the bottle neck

- IR spectroscopy (clusters >1.5) is a nightmare

2. The XXL survey

Website http://irfu.cea.fr/xxl

The XXL survey
an XMM Very Large Programme

- Builds on the XMM-LSS experience
- 2 areas of 25 deg^2 each, paved with 10 ks XMM observations
  - 3Ms allocated in December 2010
  - Some 3Ms of already existing data

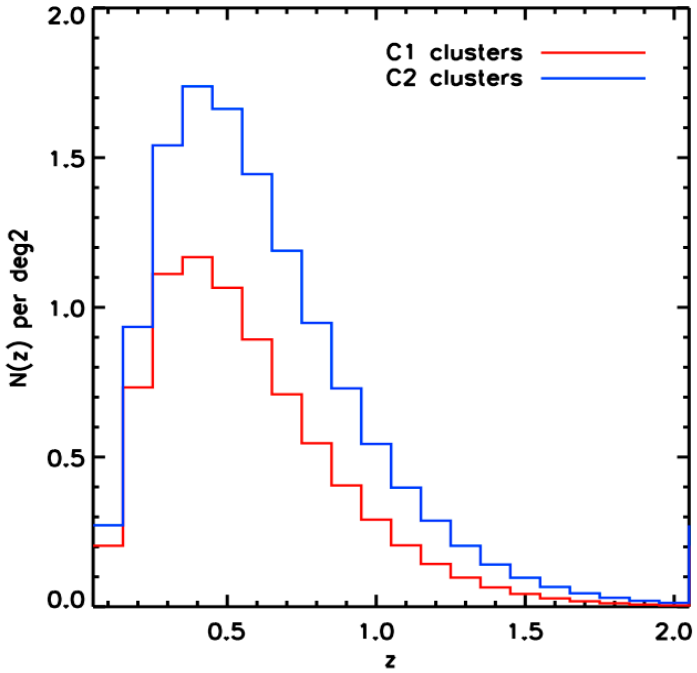
- Main science goal: the equation of state of the dark energy from clusters of galaxies

- Hot topics for AGNs and clusters and XRB

The cosmological quantities

- dn/dz

  for a given selection function



C1: 6 clusters /deg^2 ~ 1/deg^2 at z>1
C2: 12 clusters /deg^2

- ξ : 3D correlation function

➔ **ξ increases the contraints by a factor of ~ 2**

Predictions for XXL
= 50 deg^2

Table 7. Cosmological constraints. Survey configuration A2 - 50 deg^2 1/4 depth (10 ks XMM exposures) 1-σ errors on w_0 / w_a

XXL

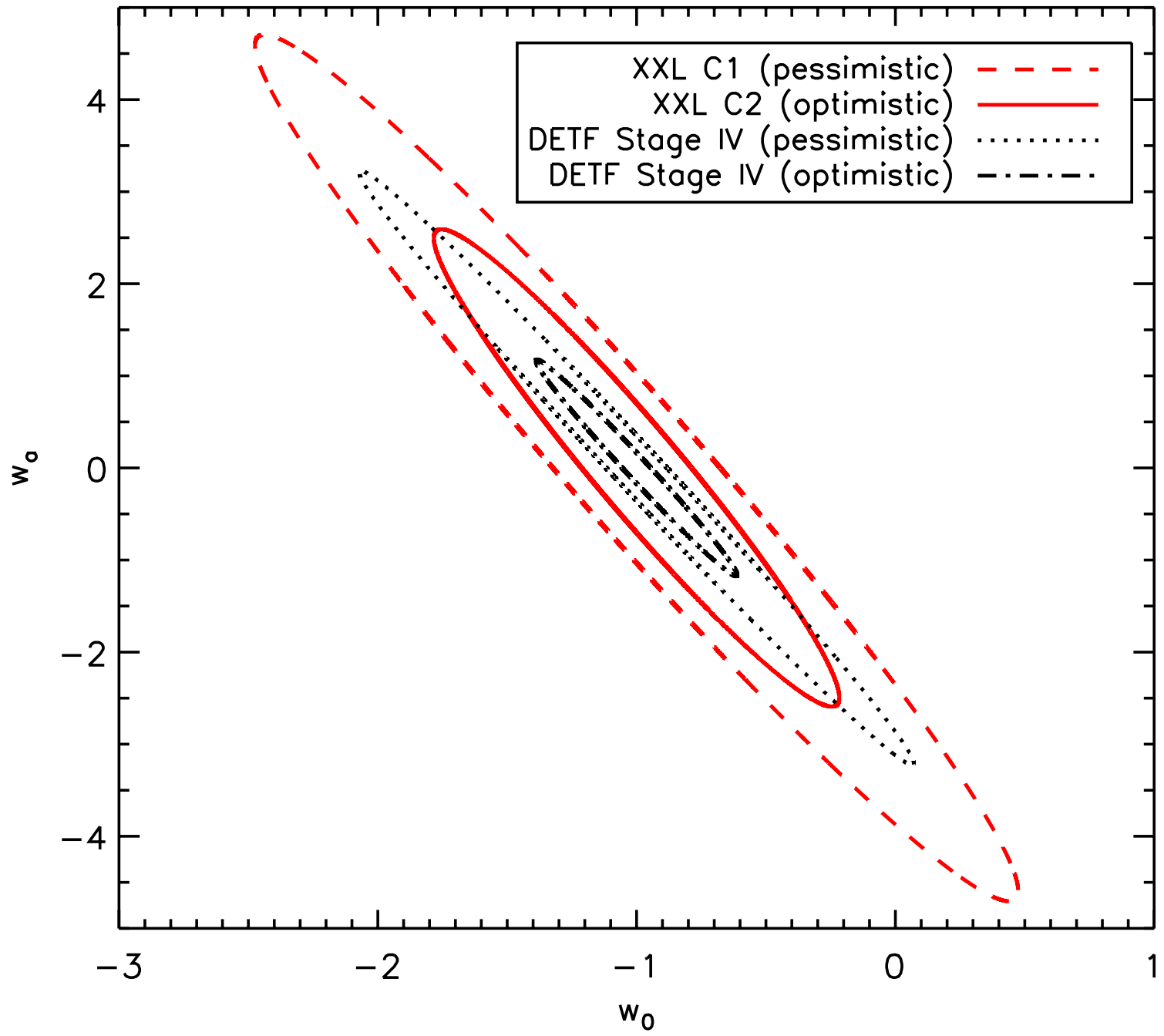
Selection	Redshift range	dn/dz + Planck	dn/dz + ξ + Planck
C1 (pessimistic)	$0 < z < 1$	2.77 / 5.98	**0.97 / 3.08**
C2 (optimistic)	$0 < z < 2$	1.14 / 2.44	**0.55 / 1.70**

Table 8. Cosmological constraints from clusters following the DETF survey designs 1-σ errors on w_0 / w_a

Ref.
Dark Energy Task Force
clusters

Stage	Pessimistic	Optimistic
III	0.70 / 2.11	0.26 / 0.77
IV	0.73 / 2.18	0.24 / 0.73

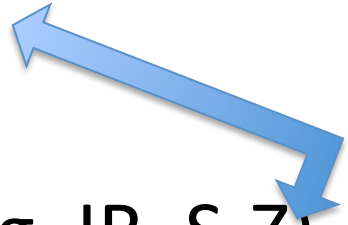
Pierre et al 2011


XXL C1 (pessimistic)
XXL C2 (optimistic)
DETF Stage IV (pessimistic)
DETF Stage IV (optimistic)
4
2
0
−2
−4
w_a
−3
−2
−1
0
1
w_0

Cluster ‘hot topics’

Specific to XXL

- The DE equation of state
- The group population at z~0.5
- Mass measurements (X, optical, lensing, IR, S-Z)
- Census of the 1<z<2 clusters
  - volume : 0.6 Gpc^3
  - comparable to the SDSS within 0<z<0.3 : 1.4 Gpc^3



AGN ‘hot topics’

Specific to XXL

More than 200 X-ray AGNs/deg2

- Large Scale Structure
- Distant / Exotic AGNs
- The statistics of lensed QSOs

Associated surveys

- **Equatorial field (LSS) 25 deg²**
  - CFHTLS, HSC — optical
  - ACTpol, AMiBA — SZ
  - UKIDSS — NIR 9 deg2
  - Spizter + SWIRE + owm
  - Herschel/HERMES — FIR 9 deg2
  - VISTA/VIDEO — deep survey 4.5 deg2
  - WIRCAM — shallow K survey
  - GMRT
  - eRosita — X
  - GAMA — spectroscopy and multi-λ z<0.5
  - VIPERS — spectroscopy (VIMOS@V
  - Euclid
- **Southern field (**
  - MIR
  - ACT, SPT — SZ
  - ATCA
  - VISTA/VHS — NIR
  - Herschel-*spire* — FIR
  - eRosita — X
  - Euclid — optical, NIR

  - … and many others in preparation (Chandra, eVLA, ASKAP, WIRCAM_deep, LOFAR….)

See complete information + maps at http://irfu.cea.fr/xxl

Black: existing or on-going or planned survey (if the area covrered is not indicated, this means that the full region 25 deg² is covered)

Pink: in preparation

Legacy

- Individual source catalogues
- Multi-λ catalogues
- Photo-z
- Special efforts on:
  - Requirements for band merging
  - Photometric uniformity

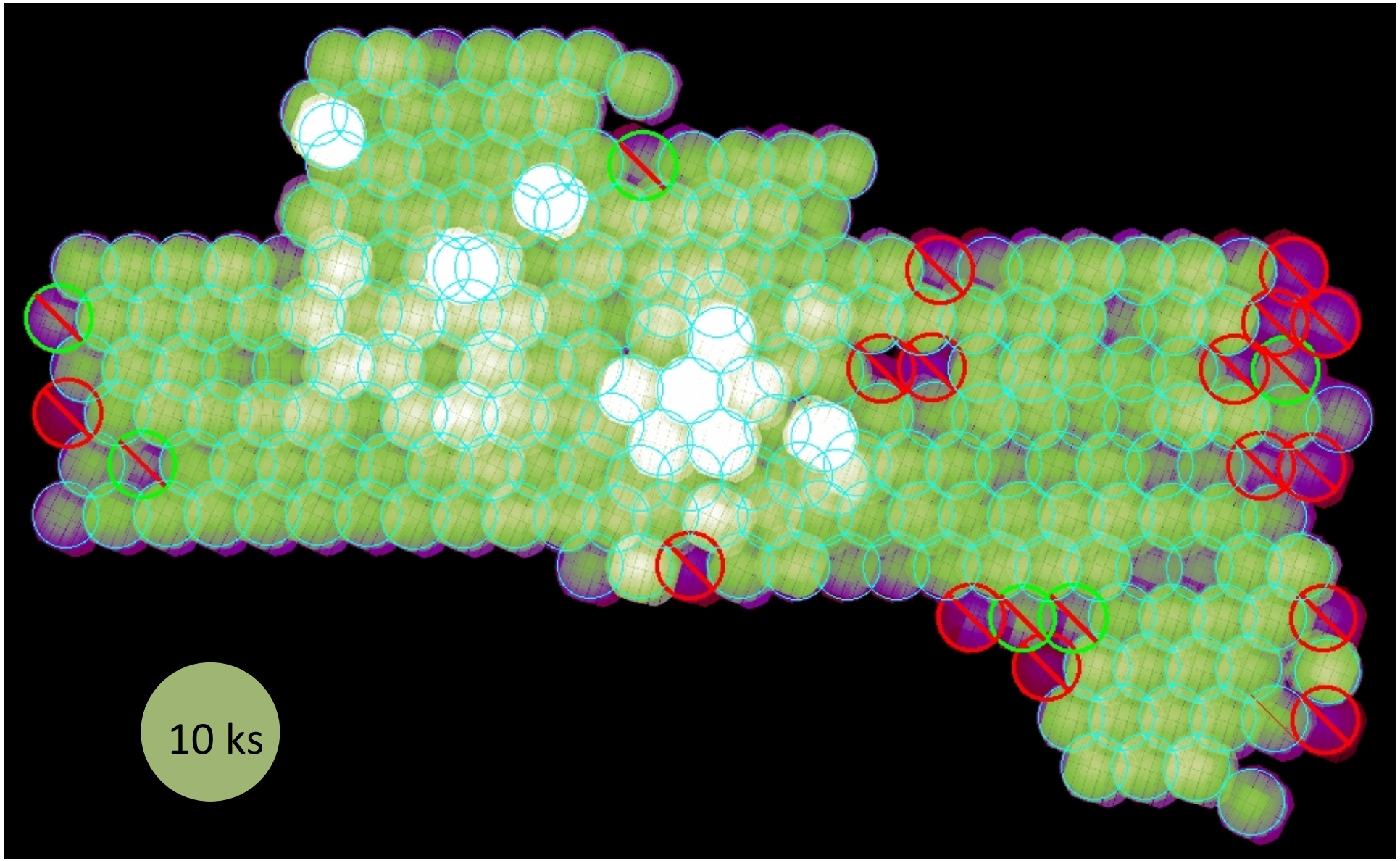
Current status

- More than 100 Co-Is
- 19 countries
- ~ 1/3 postdoc
- A few students

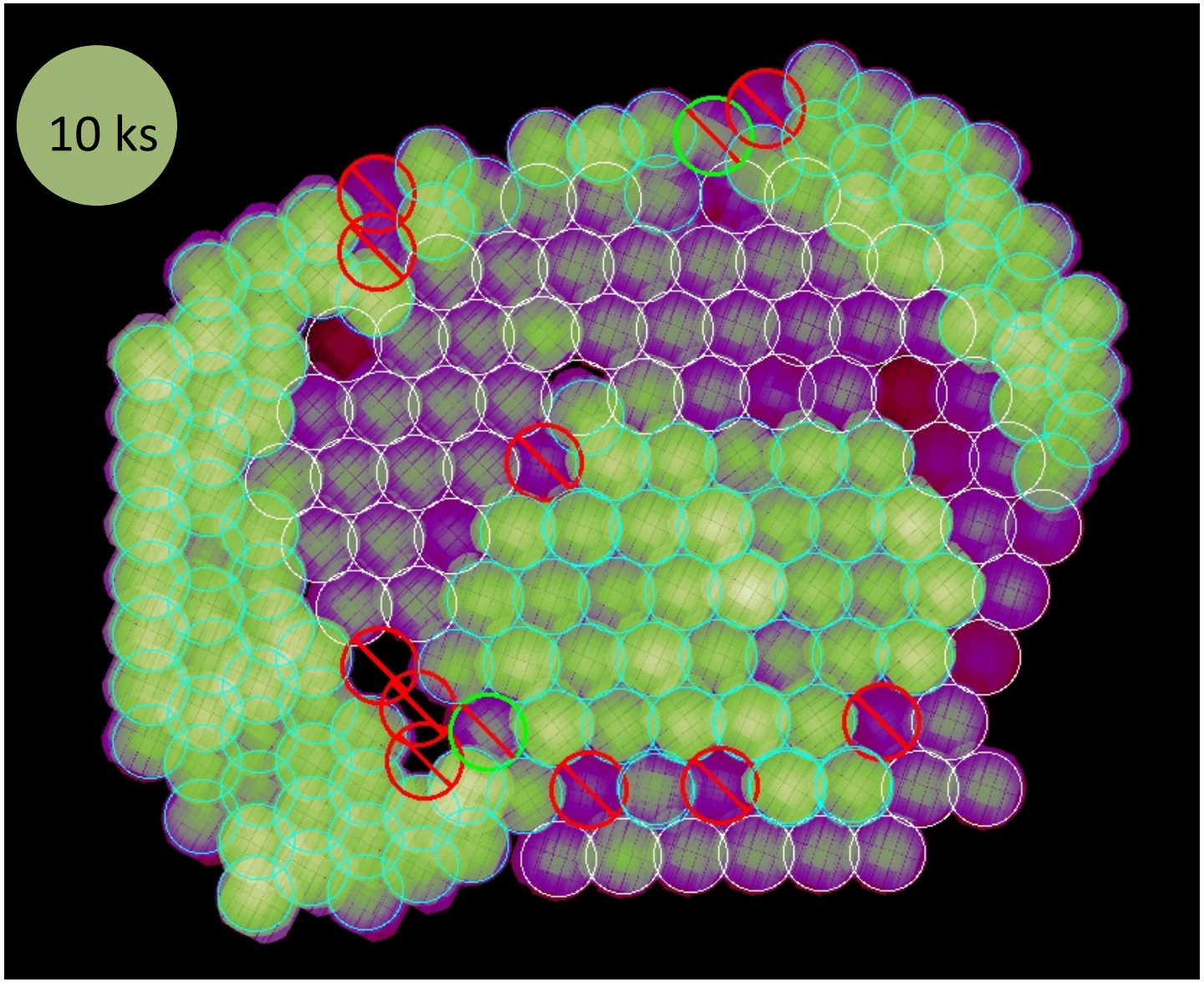
- X-ray coverage to be completed by May 2013

- More than 350 clusters to date…

LSS equatorial field



BCS southern field



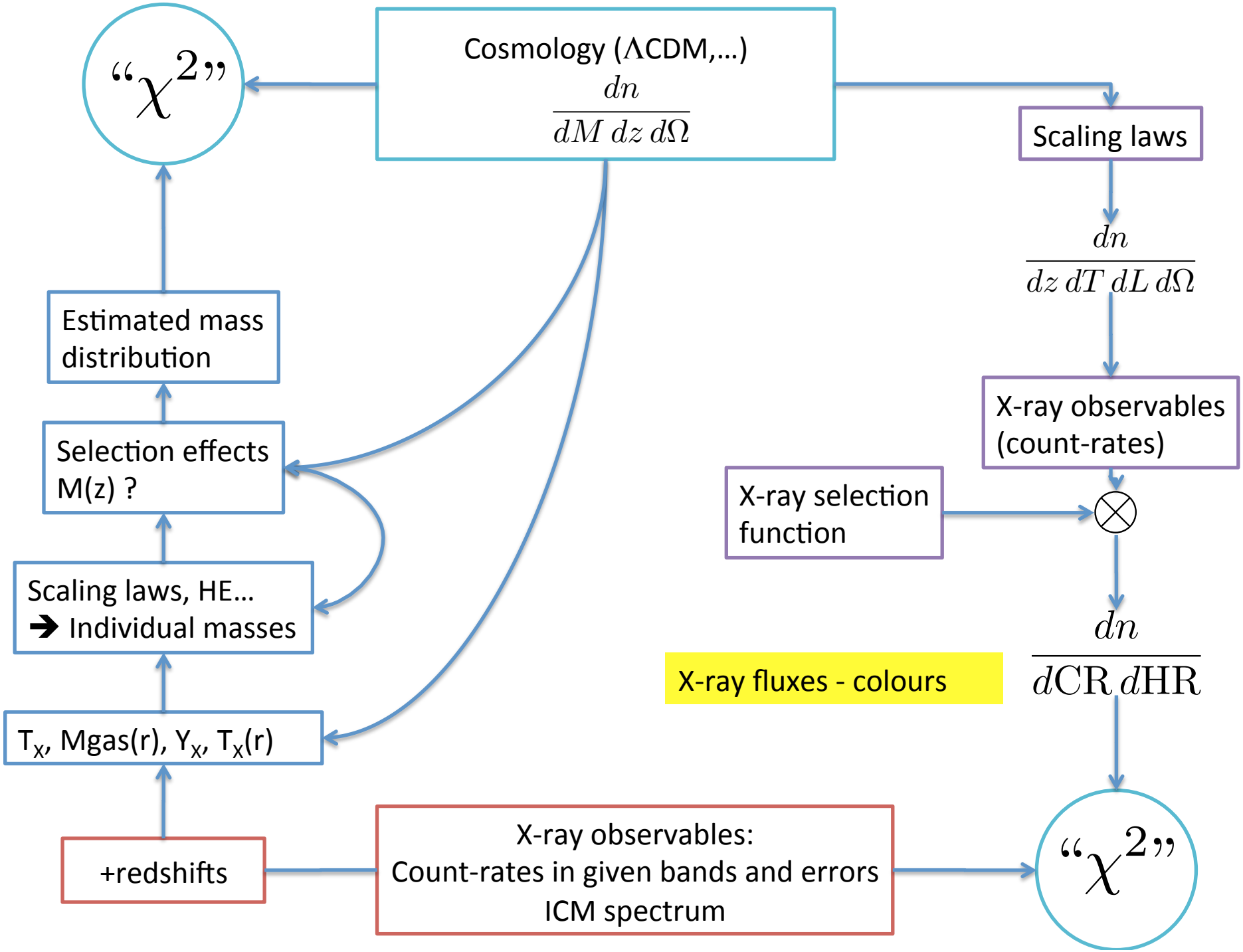
The shallow observations will be completed by mid 2013

3. A new method for analysing X-ray cluster surveys

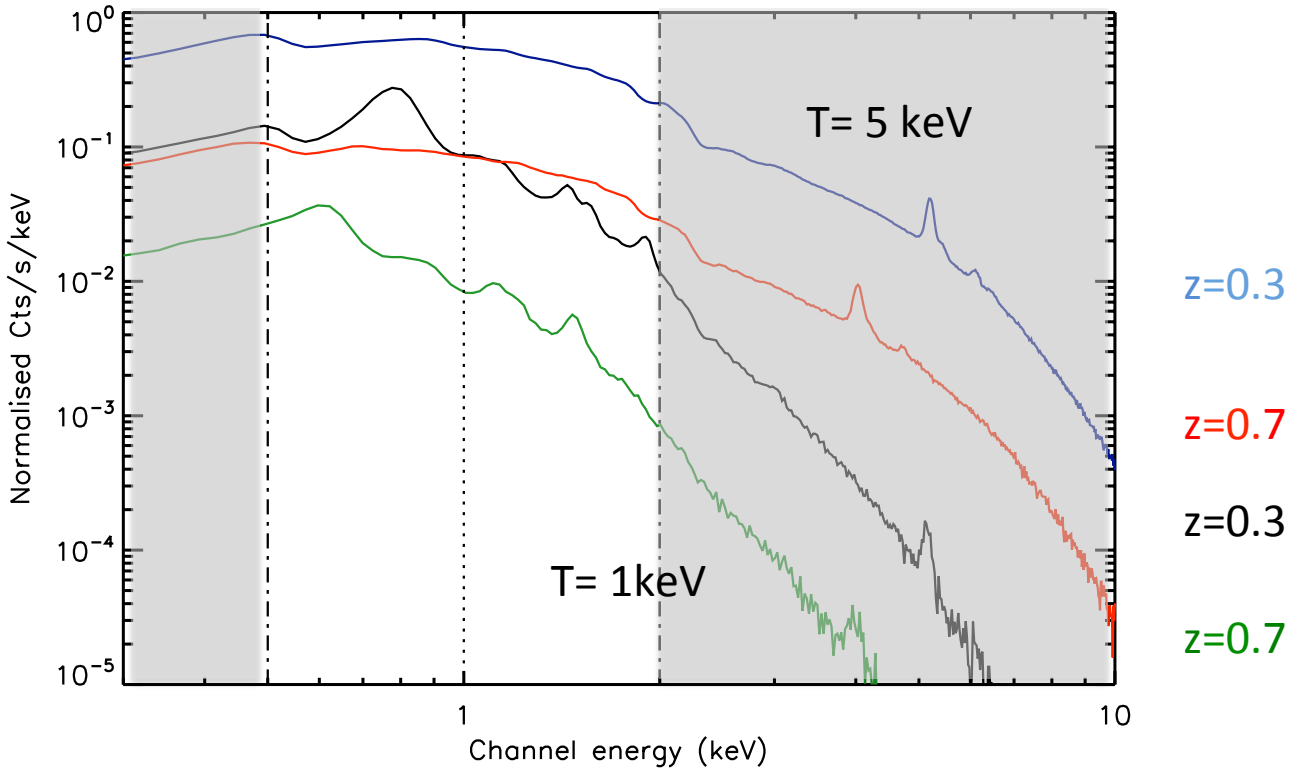
A proper analyis of cluster samples requires to simultaneously model:

- **Cosmology**
- **Cluster evolution**
- **Selection effects**

N. Clerc, M. Pierre, F. Pacaud, T. Sadibekova,
2012 MNRAS, 423, 3545
N. Clerc, T. Sadibekova, M. Pierre, F. Pacaud, J.-P. Le Fevre, C. Adami, B. Altieri, I. Valtchanov
2012 MNRAS 3545, 3583


"χ^2"
Cosmology (ΛCDM,…)
$\frac{dn}{dM\,dz\,d\Omega}$
Scaling laws
$\frac{dn}{dz\,dT\,dL\,d\Omega}$
X-ray observables (count-rates)
X-ray selection function
$\frac{dn}{d\mathrm{CR}\,d\mathrm{HR}}$
X-ray fluxes - colours
"χ^2"
X-ray observables:
Count-rates in given bands and errors
ICM spectrum
+redshifts
T_X, Mgas(r), Y_X, T_X(r)
Scaling laws, HE…
➔ Individual masses
Selection effects
M(z) ?
Estimated mass distribution

- CR in [0.5-2] keV (~flux)
- HR = [1-2]/[0.5-1] (~spectrum)



The CR-HR distribution

[1-2] keV / [0.5-1] keV hardness ratio (HR)

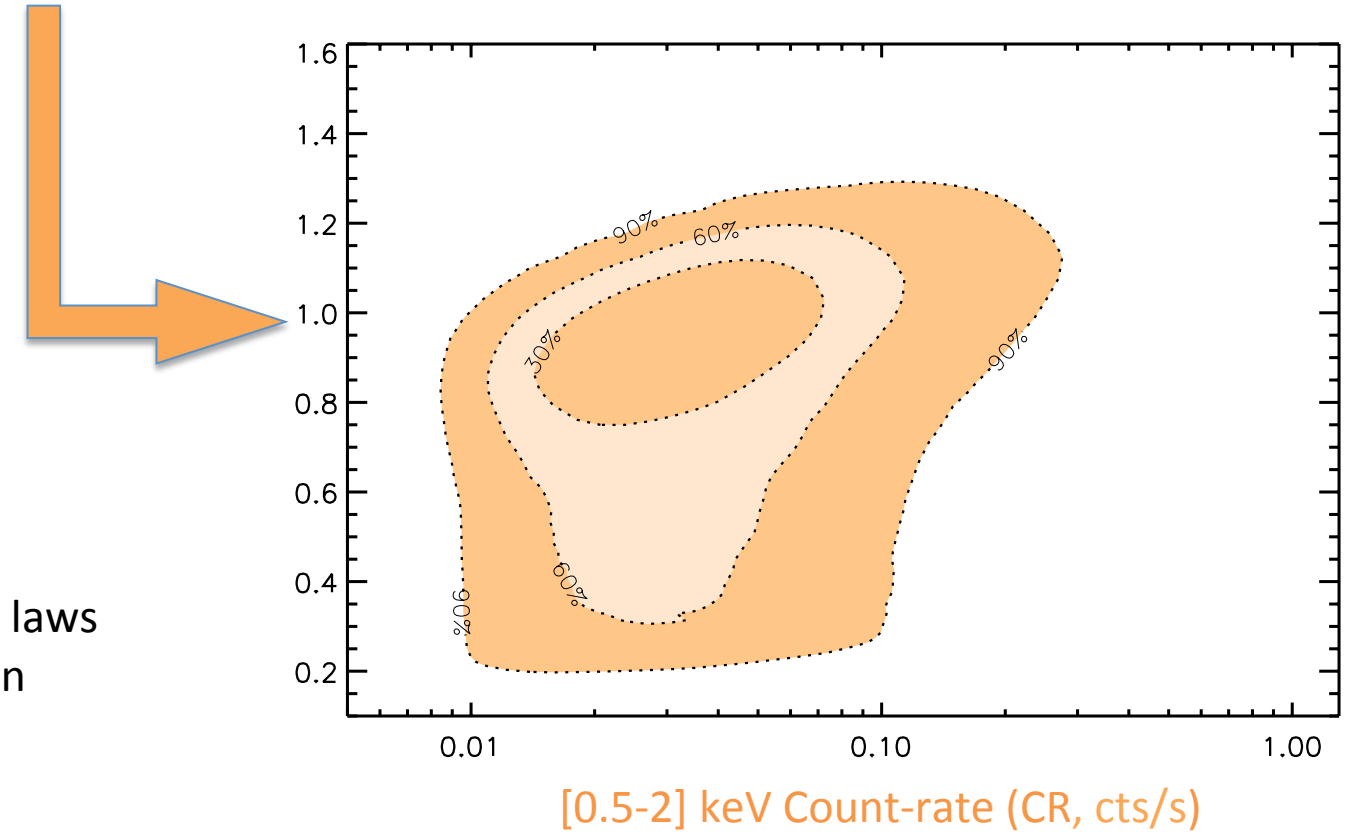
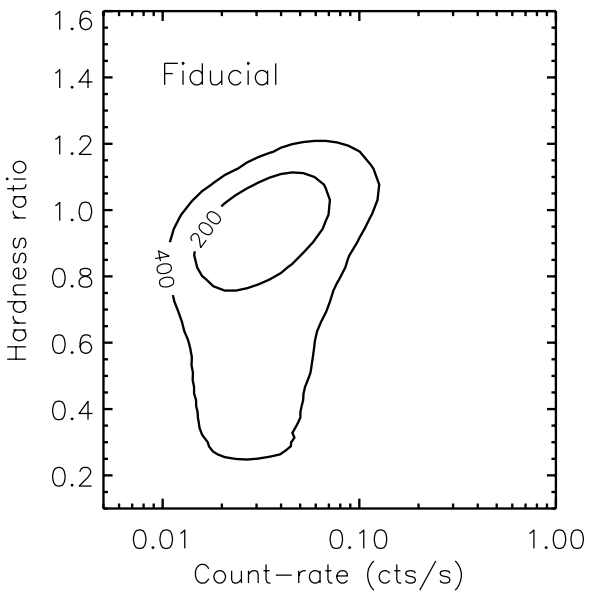
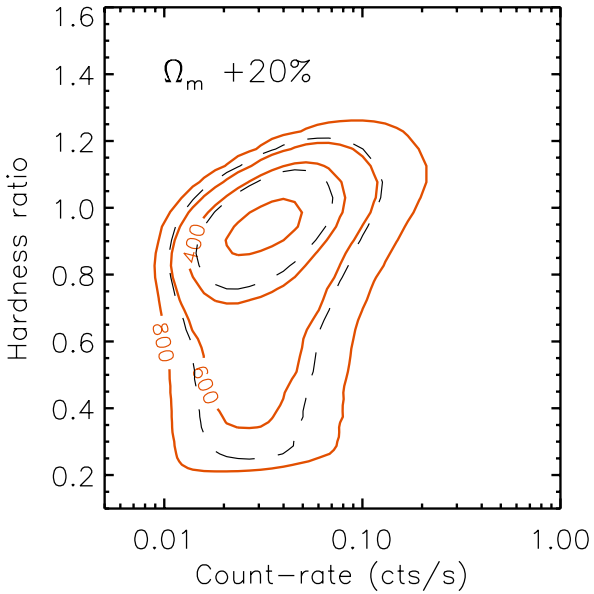


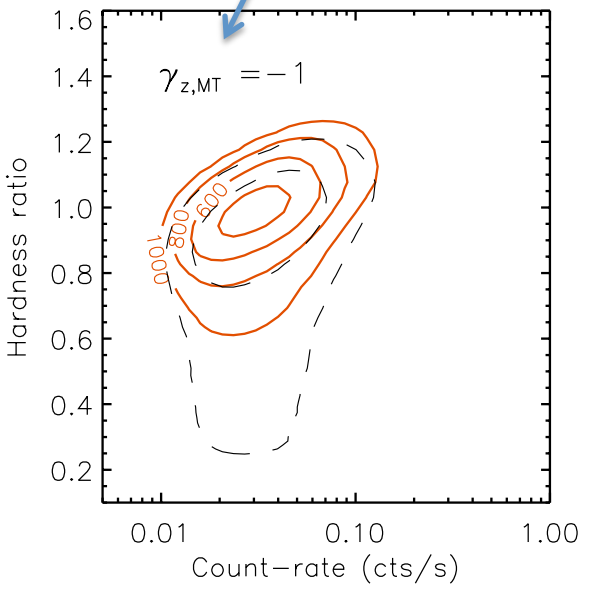
Diagram computed for :

- WMAP5 cosmology
- C1 selection
- Local cluster scaling laws
- Self-similar evolution

Non self-similar evolution

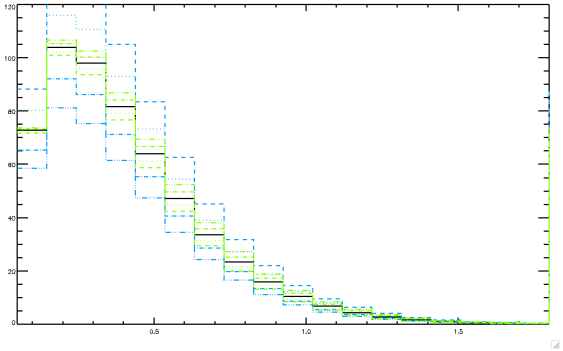




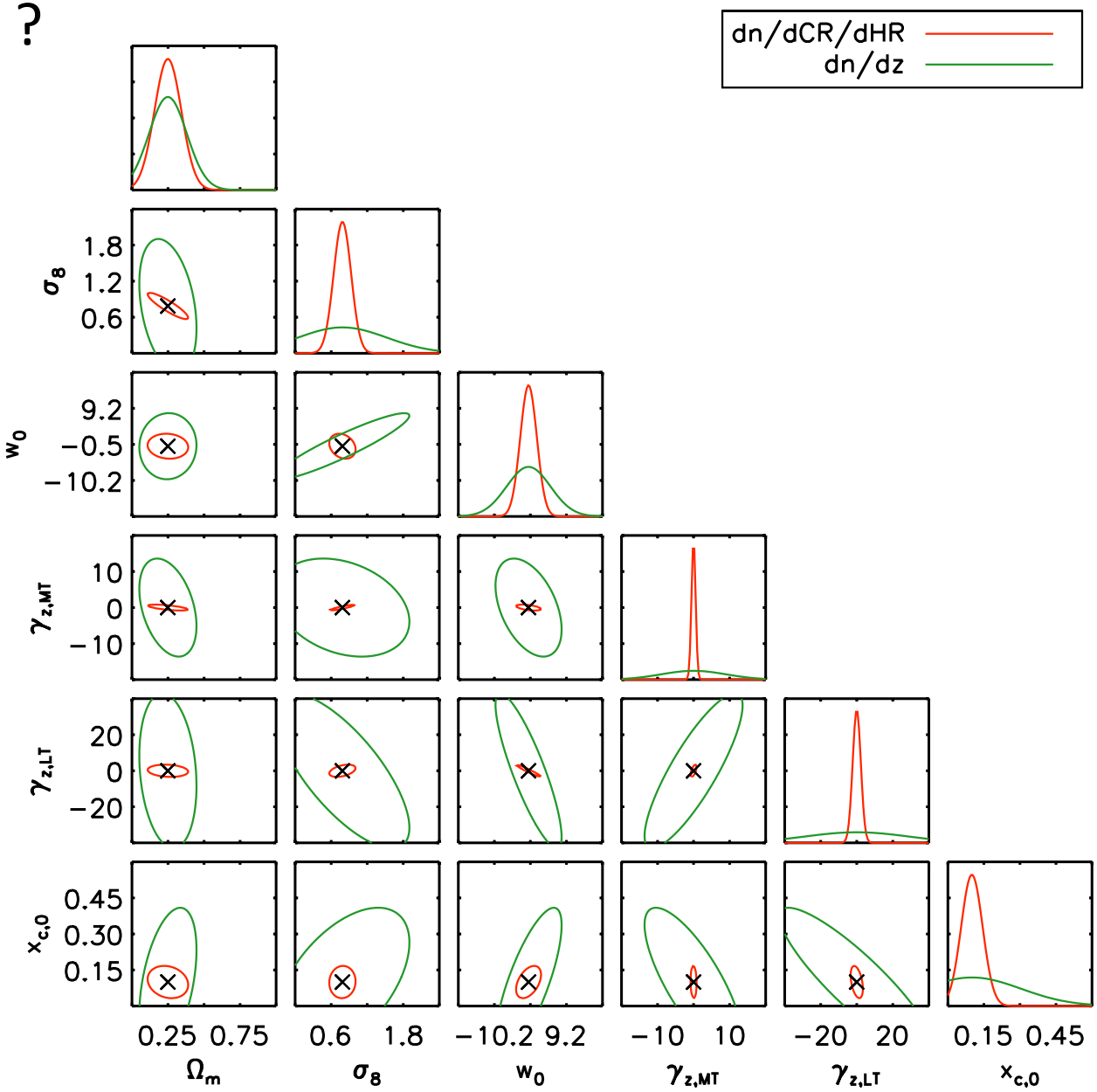


Adding redshifts

1) Is dn/dz sufficient ?

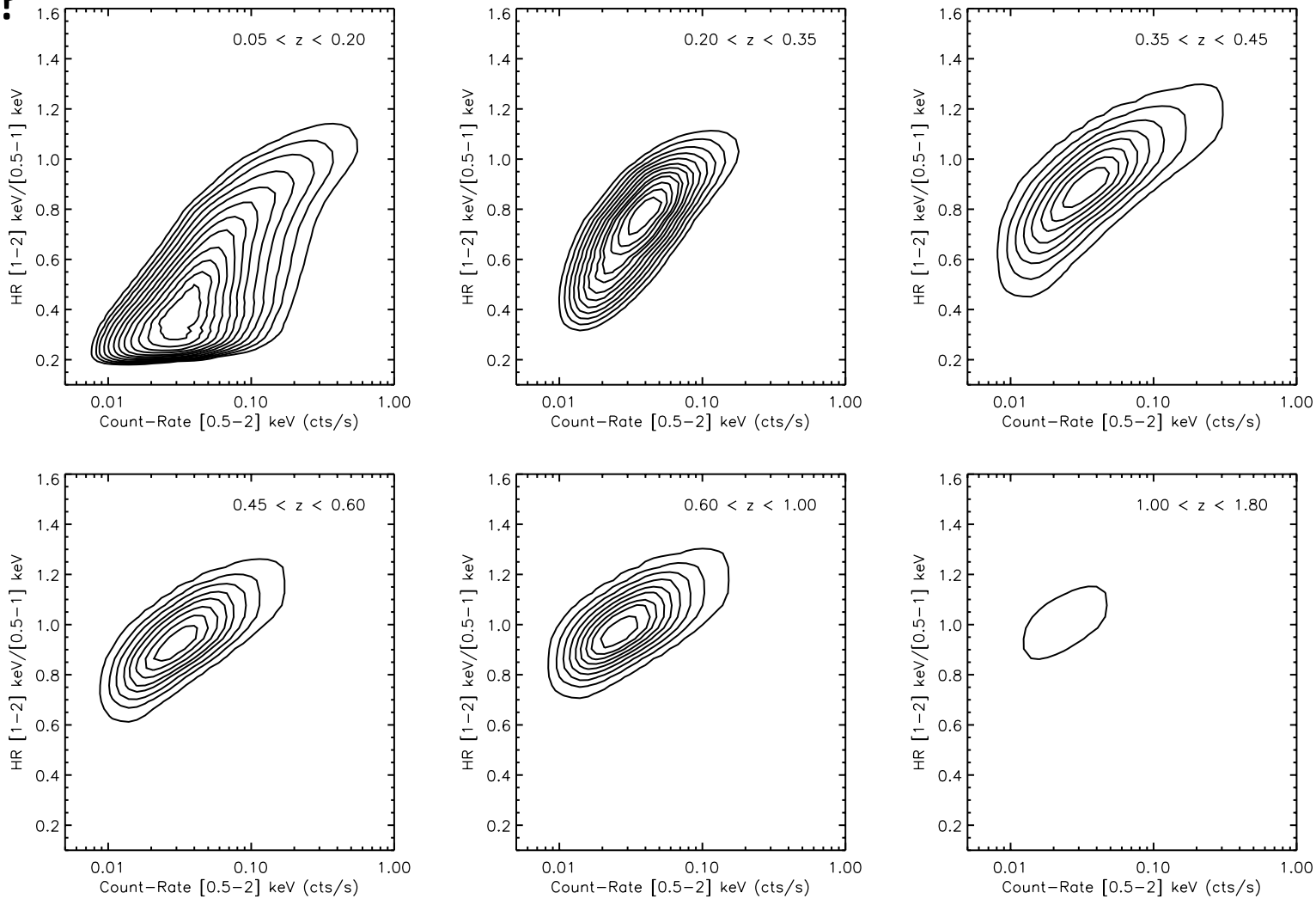


No, degeneracies



Adding redshifts

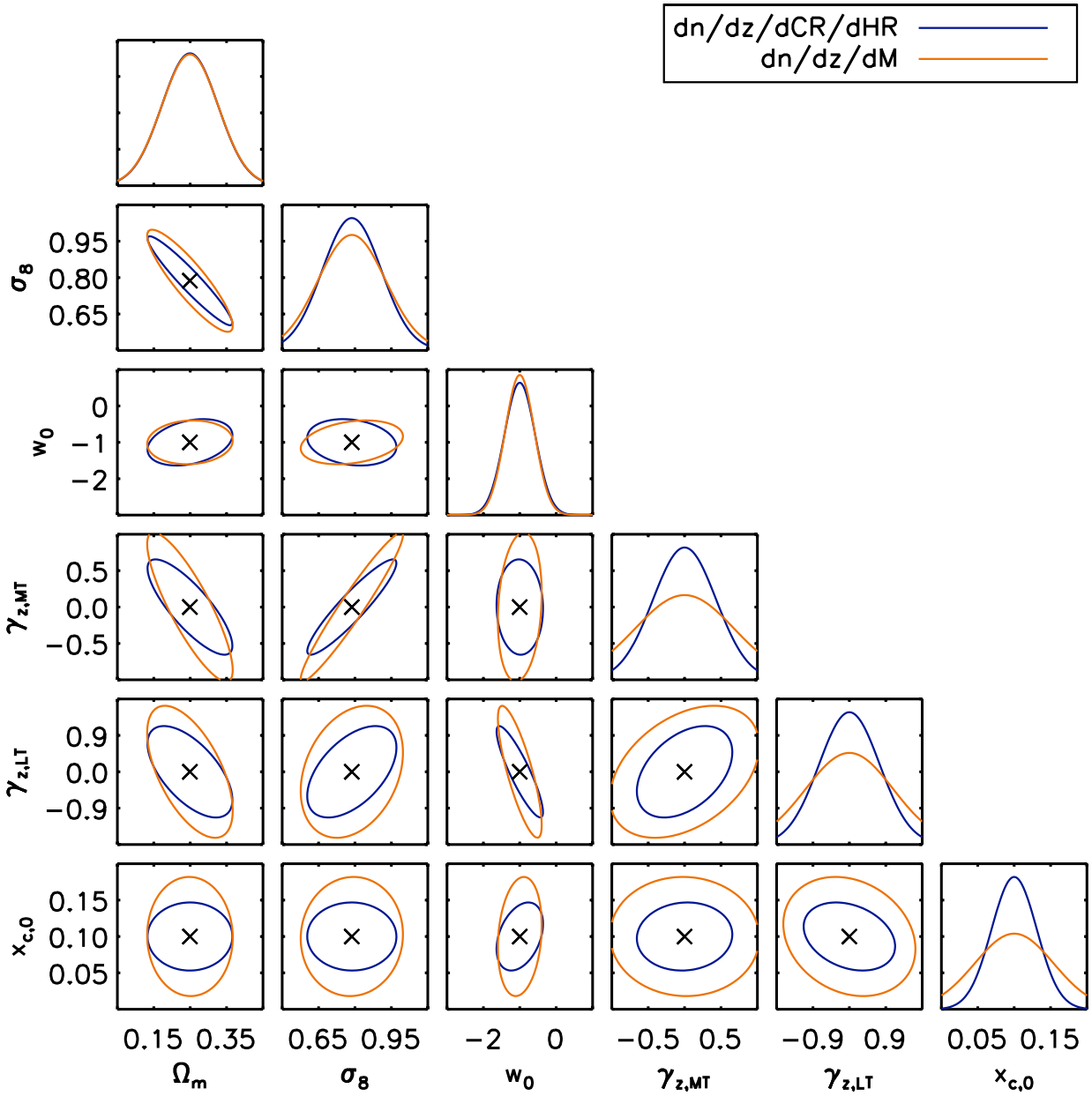
2) 3rd dimension to the diagram?



Adding redshifts

3) Calculating masses ?

- $T_X \rightarrow M$
- dn/dz/dM
- measurement errors (z and M)



The X-Class cluster catalogue

(Clerc et al 2012)

- **845 clusters from the XMM All-Sky archive**
- 220 « new » (not in NED, not in XCS-DR1)
- Dedicated database

id	xclass	name	R.A. *pipeline measured*	DEC *pipeline measured*	NED	quality	class	obs	main	nb links	redshift	status	total rate	profile
20	0020	0001930301_84_v3.3_c1_10ks	193.438 193.438	10.195 10.195	-	1	z > 0.3	0001930301_10ks					0.052	data
23	0023	0010420201_53_v3.3_c1_10ks	194.292 194.292	-17.412 -17.406	21	1	0 < z <~ 0.3	0010420201_10ks			0.047	confirmed	12.622	data
33	0033	0030140101_1_v3.3_c1_10ks	193.679 193.674	-29.223 -29.223	7	1	0 < z <~ 0.3	0030140101_10ks			0.053	confirmed	4.290	data
34	0034	0030140101_3_v3.3_c1_10ks	193.595 193.593	-29.016 -29.013	25	1	0 < z <~ 0.3	0030140101_10ks			0.053	confirmed	3.667	data
35	0035	0032141201_44_v3.3_c1_10ks	196.274 196.274	-10.280 -10.279	-	1	z > 0.3	0032141201_10ks			0.330	photometric	0.047	data
38	0038	0037981801_11_v3.3_c1_10ks	36.567 36.568	-2.666 -2.666	1	1	0 < z <~ 0.3	0037981801_10ks					0.165	data
39	0039	0037981801_112_v3.3_c1_10ks	36.499 36.499	-2.827 -2.828	1	1	0 < z <~ 0.3	0037981801_10ks			0.280	confirmed	0.031	data
40	0040	0037982601_56_v3.3_c1_10ks	35.188 35.189	-3.434 -3.434	1	1	z > 0.3							data

http://xmm-lss.in2p3.fr:8080/l4sdb/

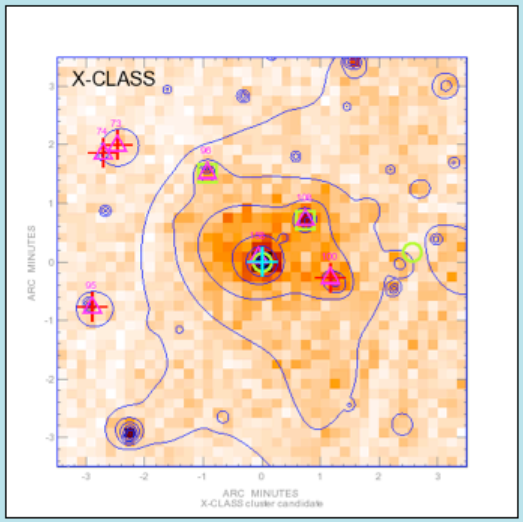
Images (X, opt)

id	xclass	name	profile
20	0020	0001930301_84_v3.3	data
23	0023	0010420201_53_v3.3	data
33	0033	0030140101_1_v3.3_	data
34	0034	0030140101_3_v3.3_	data
35	0035	0032141201_44_v3.3	data
38	0038	0037981801_11_v3.3	data
39	0039	0037981801_112_v3.	data
40	0040	0037982601_56_v3.3	data

Cluster candidate : 0203610401_158_v3.3_c1_20ks id : 1899

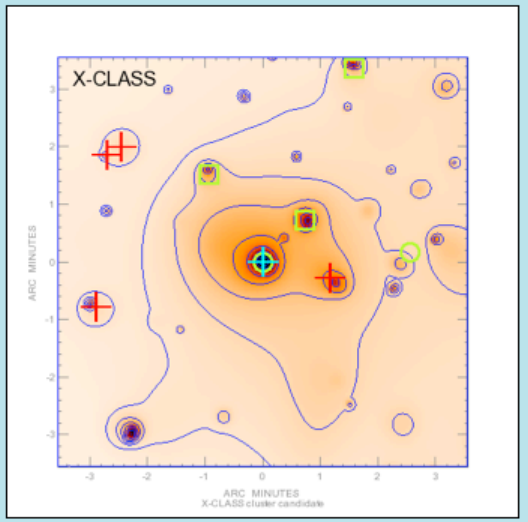
Xray Overlays

0203610401_158_v3.3_c1_20ks_rawraw.png



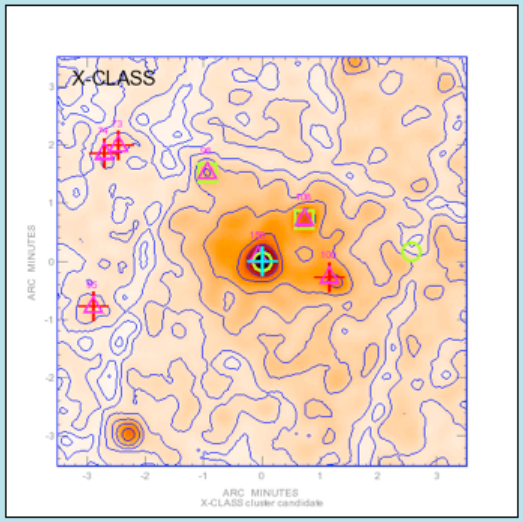
Raw X-ray image + raw contours

0203610401_158_v3.3_c1_20ks_wavewave.png



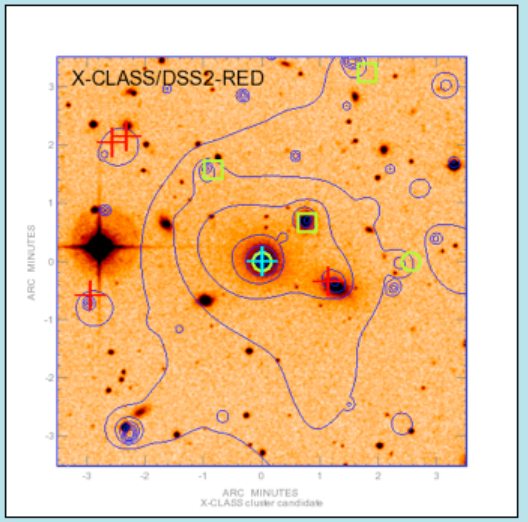
Wavelet image + wavelet contours

0203610401_158_v3.3_c1_20ks_gaussgauss.png



Gaussian smoothed image (sigma=3pixels) + gaussian contours

0203610401_158_v3.3_c1_20ks_optwave.png

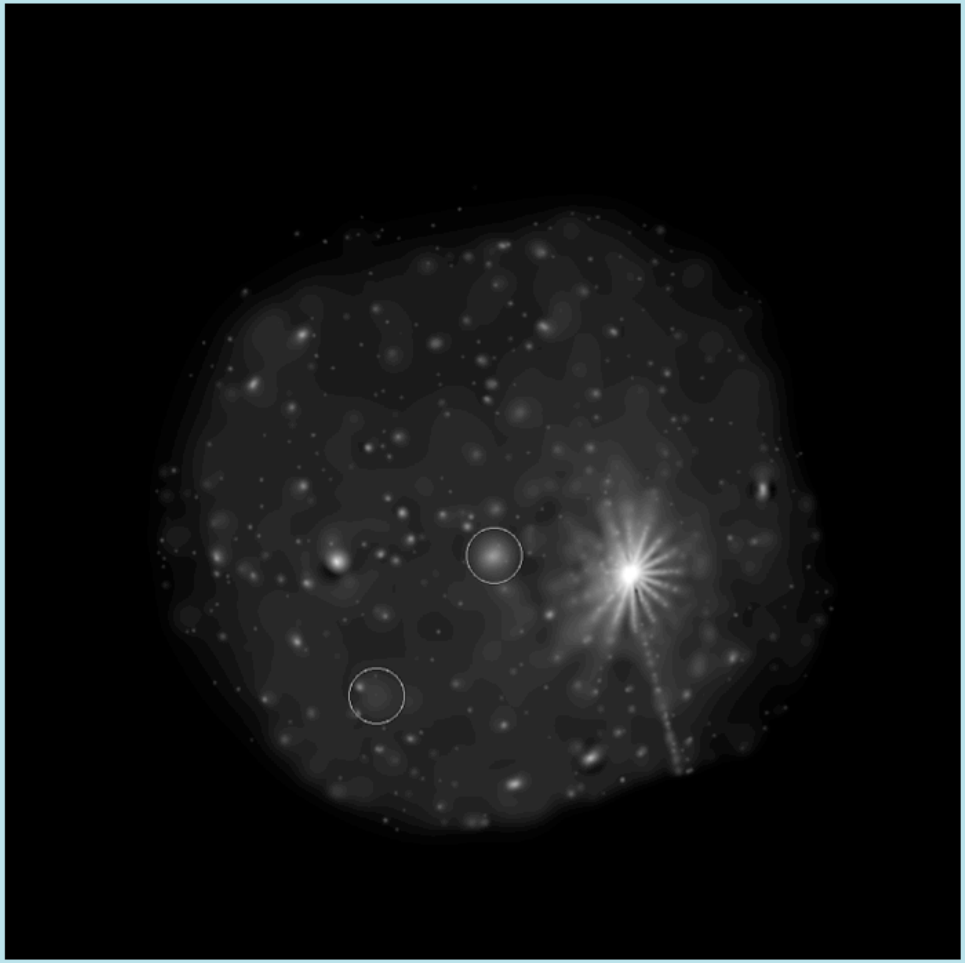


DSS2 band image + wavelet contours

Cluster : 0300140101_64_v3.3_c1_20ks id : 1960

Observation : 0300140101_20ks
Target : Cl1429.0+4241
Preprocessing version : Py-2.0

Wavelet filtered (M1+M2+PN) image. White circles show the locations of C1 clusters over the pointing.



Pointing overview

obs	main	nb links	redshift	status	total rate	profile
0001930301_10ks					0.052	data
0010420201_10ks			0.047	confirmed	12.622	data
0030140101_10ks			0.053	confirmed	4.290	data
0030140101_10ks			0.053	confirmed	3.667	data
0032141201_10ks			0.330	photometric	0.047	data
0037981801_10ks					0.165	data
0037981801_10ks			0.280	confirmed	0.031	data

40	0040	0037982601_56_v3.3_c1_10ks	35.188 35.189	-3.434 -3.434	1	1	z > 0.3	data

http://xmm-lss.in2p3.fr:8080/l4sdb/

id	xclass	name	R.A. *pipeline measured*	DEC *pipeline measured*	dshift	status	total rate	profile
20	0020	0001930301_84_v3.3_c1_10ks	193.438 193.438	10.195 10.195			0.052	data
23	0023	0010420201_53_v3.3_c1_10ks	194.292 194.292	-17.412 -17.406	0.047	confirmed	12.622	data
33	0033	0030140101_1_v3.3_c1_10ks	193.679 193.674	-29.223 -29.223	0.053	confirmed	4.290	data
34	0034	0030140101_3_v3.3_c1_10ks	193.595 193.593	-29.016 -29.013	0.053	confirmed	3.667	data
35	0035	0032141201_44_v3.3_c1_10ks	196.274 196.274	-10.280 -10.279	0.330	photometric	0.047	data
38	0038	0037981801_11_v3.3_c1_10ks	36.567 36.568	-2.666 -2.666			0.165	data
39	0039	0037981801_112_v3.3_c1_10ks	36.499 36.499	-2.827 -2.828	0.280	confirmed	0.031	data
40	0040	0037982601_56_v3.3_c1_10ks	35.188 35.189	-3.434 -3.434				data

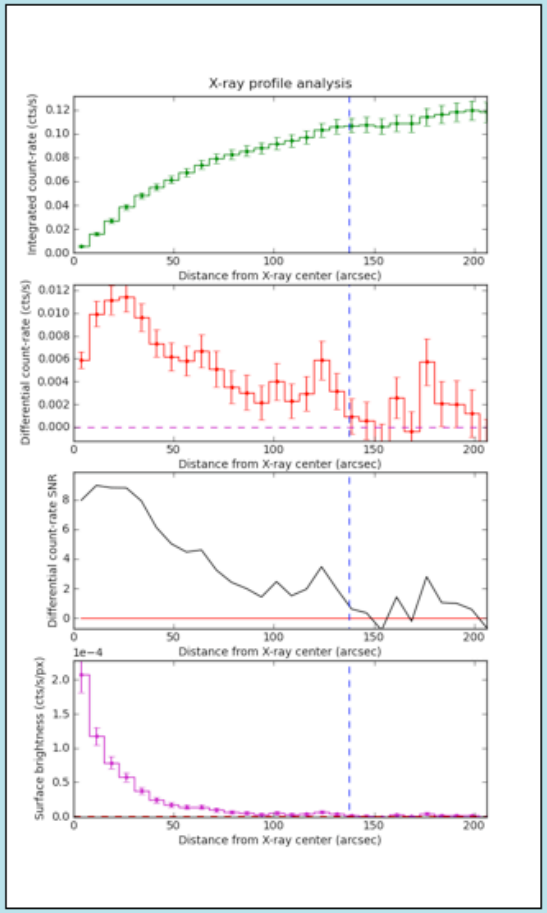
Cluster : 0056022201_1_v3.3_c1_10ks id : 634

CR1	b2 [0.5-2 keV]	0.107	error	0.006
CR2	b3 [2-10 keV]	0.025	error	0.006
CR3	b21 [0.5-0.9 keV]	0.047	error	0.004
CR4	b24 [1.3-2 keV]	0.030	error	0.003
CR5	b31 [2-5 keV]	0.032	error	0.005
CR6	b33 [5-7 keV]	0.013	error	0.003

Unit : c/s

R fit	137.5	arcsec
N_H	5.4	$\cdot 10^{20}$ cm^{-2}

Profile



Vertical dash › blue line: Limit of the interactive integration

Count-rate measurem.

3.fr:8080/l4sdb/

CONCLUSION

XXL = DE now!

Very exciting coming 5 years

In addition to DE and AGN science:

XXL will provide a wonderful legacy data set over 50 deg2 to:

- Cross- check the **optical-IR** ⇔ **X-ray cluster selection functions**

- Study the biases of the different cluster approaches to cosmology
  - **X-ray**
  - **Optical**
  - **Lensing**
  - **S-Z**
  - ➔ **Perform the combined cosmological analysis**

- Provide a reference/calibration area for the next generation surveys
  - eRosita
  - Euclid
  - LSST

The END