X
X
L

The ultimate
XMM extragalactic survey

die Kunst über in der Wissenschaft

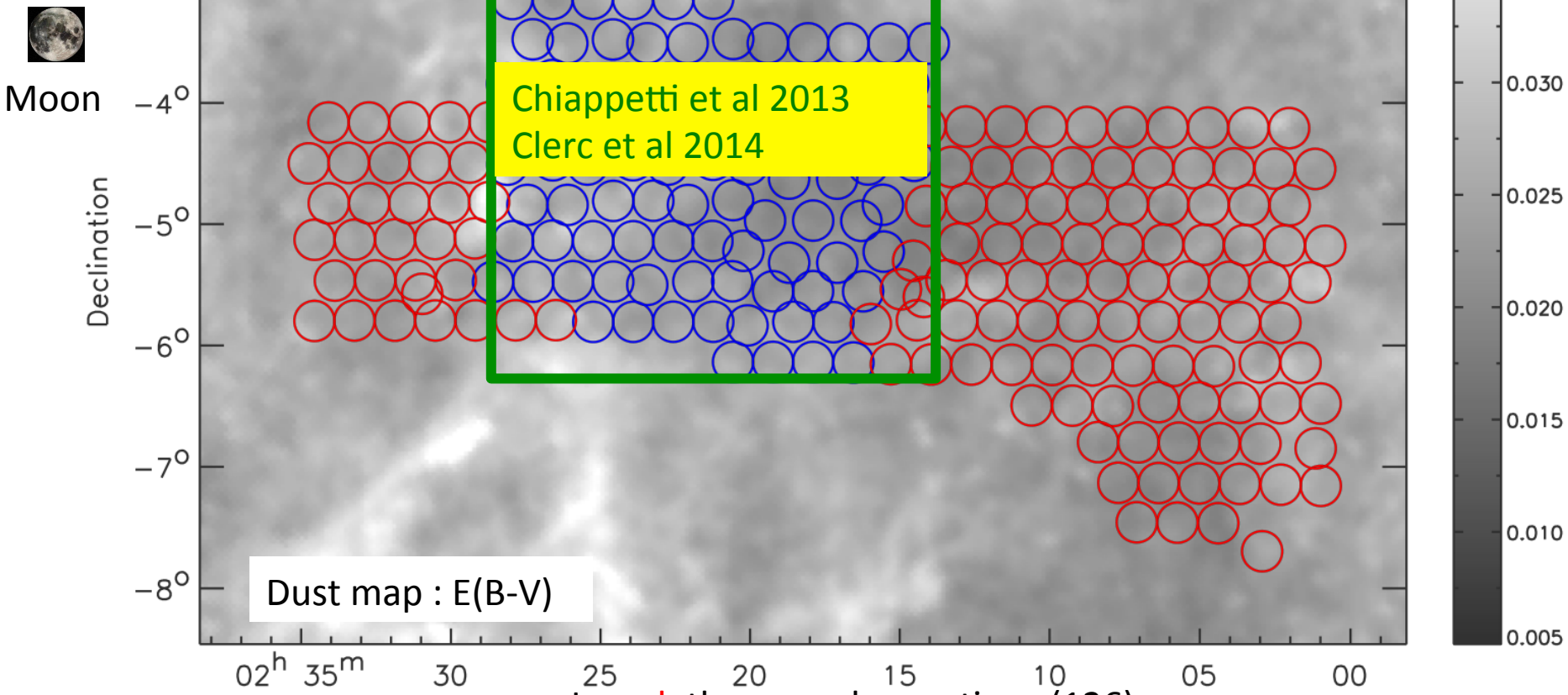
XXL

The ultimate
XMM extragalactic survey

M. Pierre, *CEA Saclay, France*
F. Pacaud and the XXL consortium

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

10 ks obs. (extension of the XMM-LSS field)

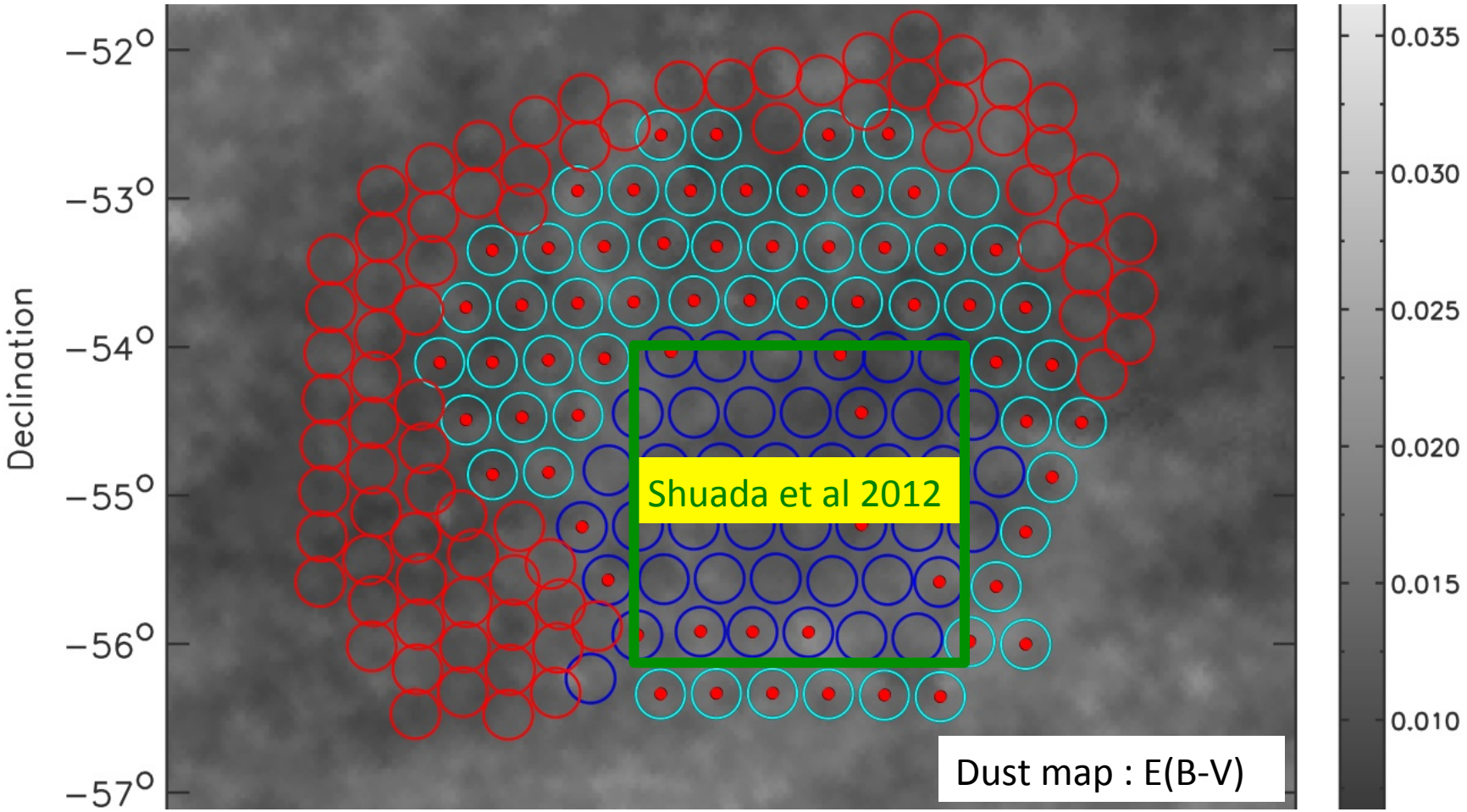


In red: the new observations (126)

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

25 deg^2 in BCS-SPT 23h30 -55d00

10 ks obs. (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. Preliminary results

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

1. Lessons from XMM-LSS

a pilot survey (2000-2010)

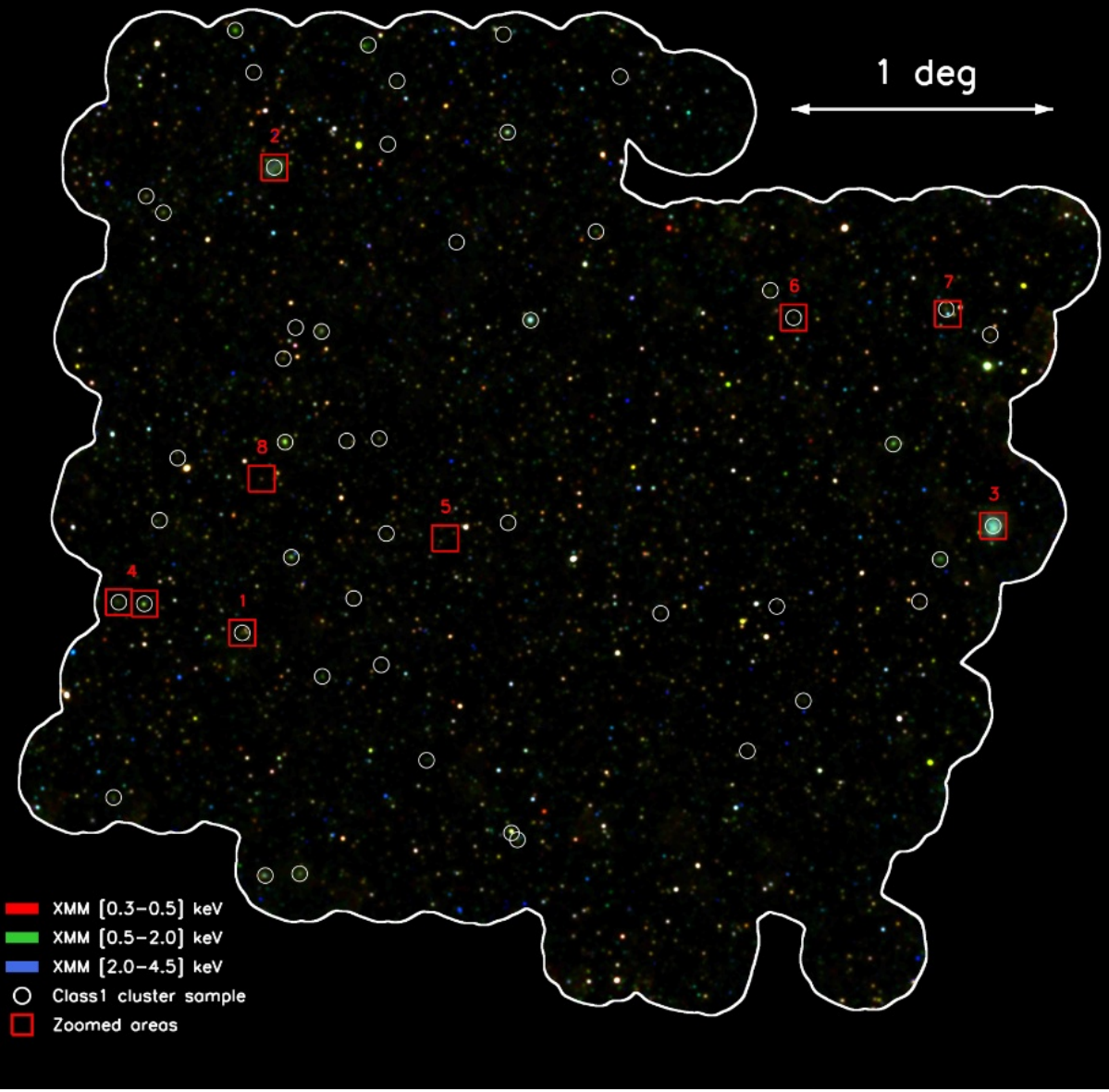
36 referred publications, 7 PhD theses

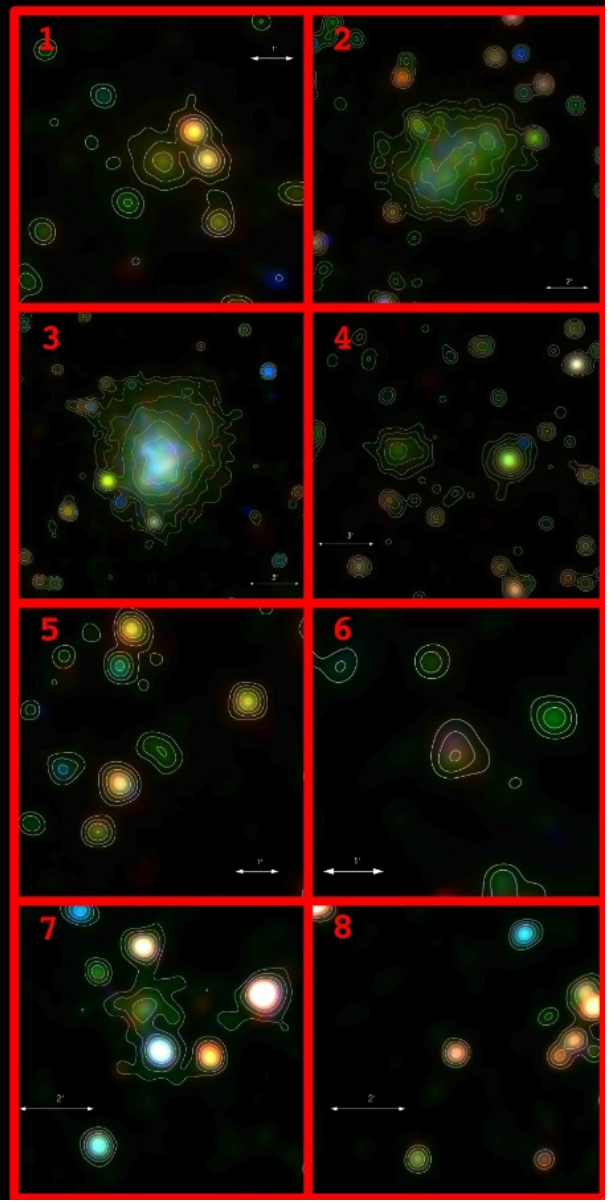
The XMM-LSS field

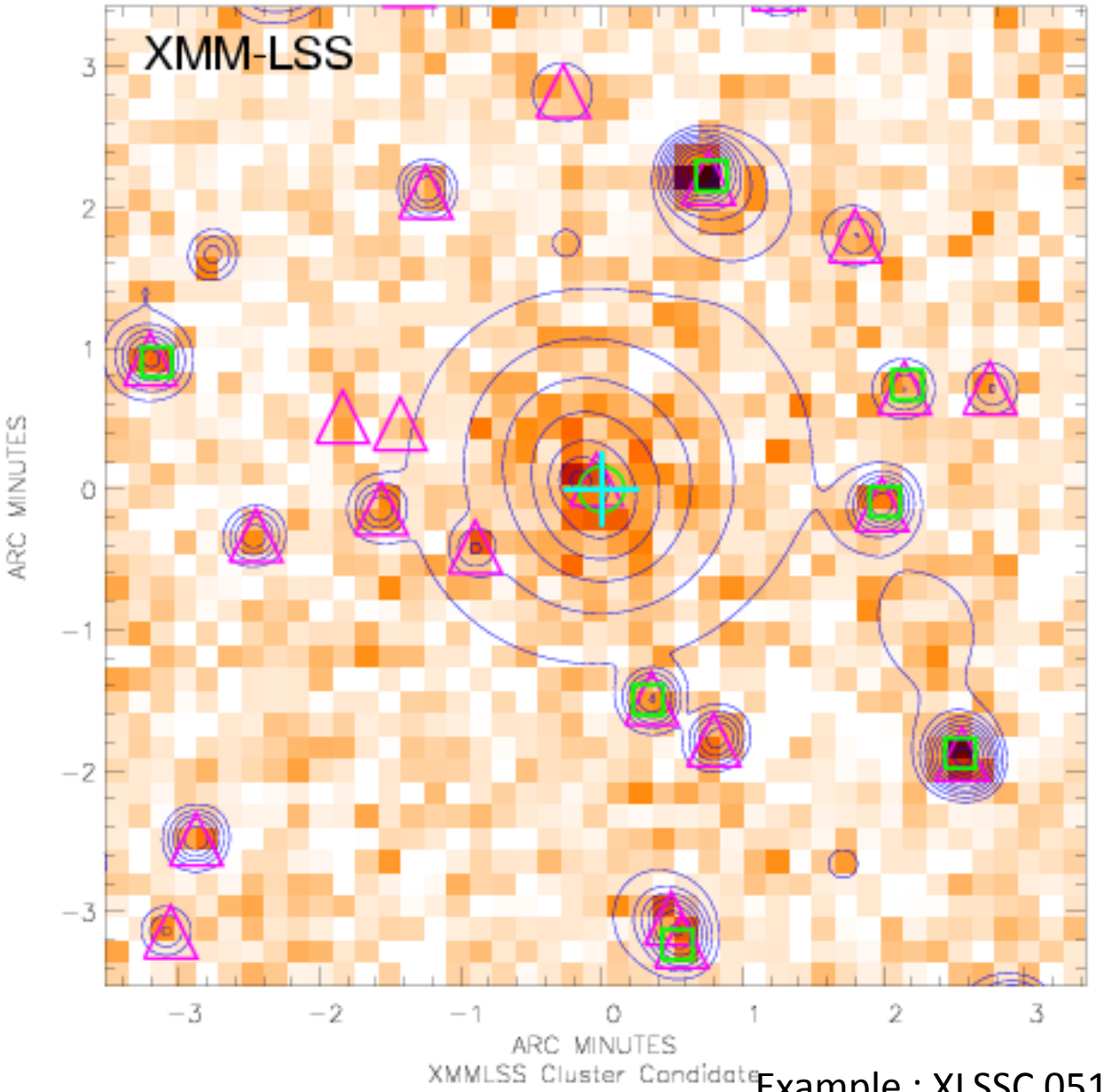
- 11 deg2 paved with 10-20 ks and including the SDS : 99 observations separated by 20'
- Optical coverage by the CFHTLS
- IRAC + MIPS survey from SWIRE
- Plus many others (VLA, GMRT, Integral, …)

The XMM-LSS survey

~ 5,600 sources !

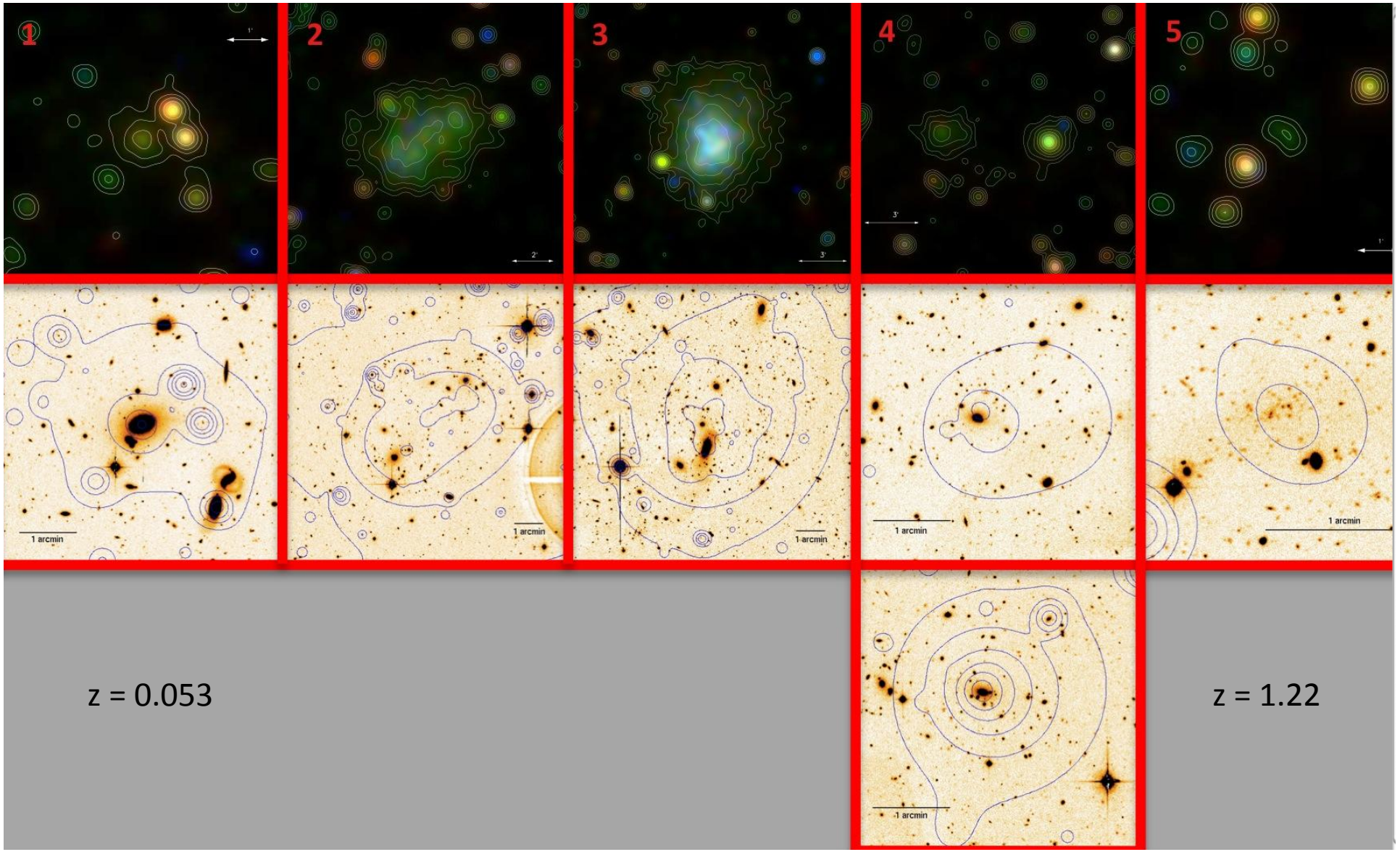






Example : XLSSC 051 *(Pacaud et al. 2007)*
z=0.27
300 counts in 0.5-2 keV

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



1) An unambiguous selection function

Cluster cosmology requires a handle on dn/dM (z), but:

- **Cluster masses are not directly observable**
- **➔ Some scaling relations between L, T and M are needed**

- To model the **observed** dn/dM(z) it is highly desirable to have **a purely X-ray selected cluster sample**
  = *ab initio* modeling

- Clusters are extended sources ➔ **a 2-D selection function**

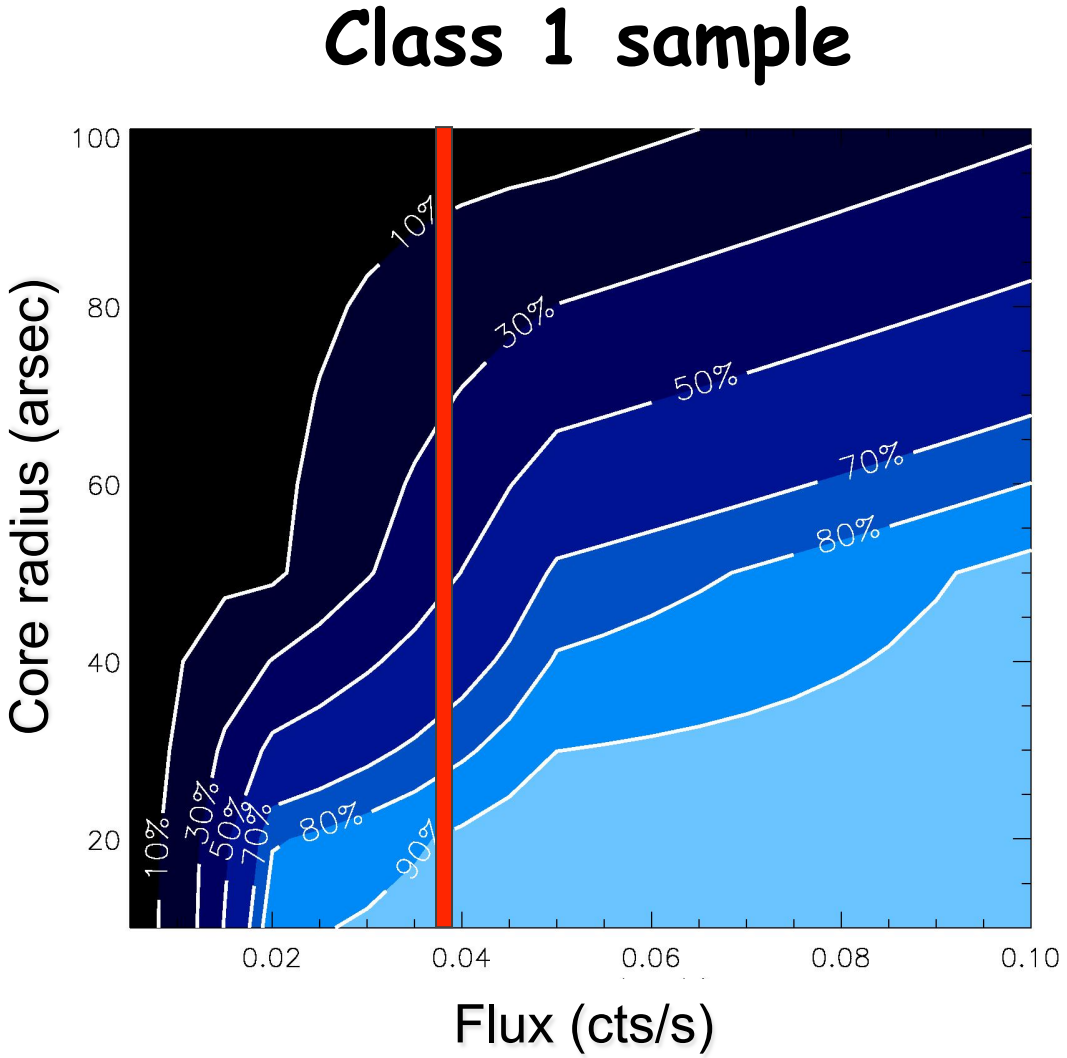
  Pacaud et al 2006, 2007

Not a flux limit !

Detection rates from extensive simulations

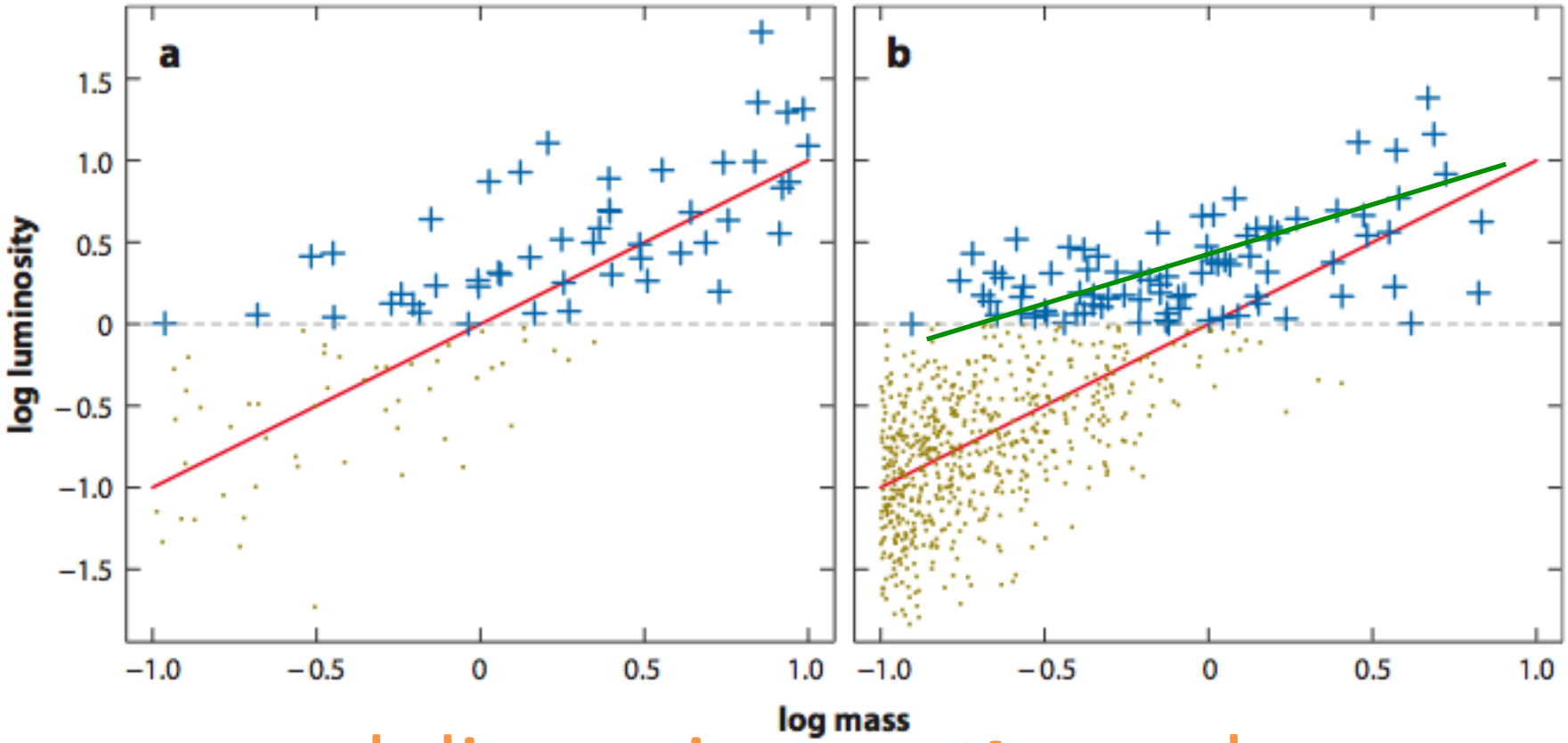
Not a flux limit !

~ surface brightness limited



Pacaud et al 2006

2) Selction effects are critical in the determination of the scaling relations…



…and dispersion **matters** a lot

Pacaud et al 2007

Allen, Evrard, Mantz 2011

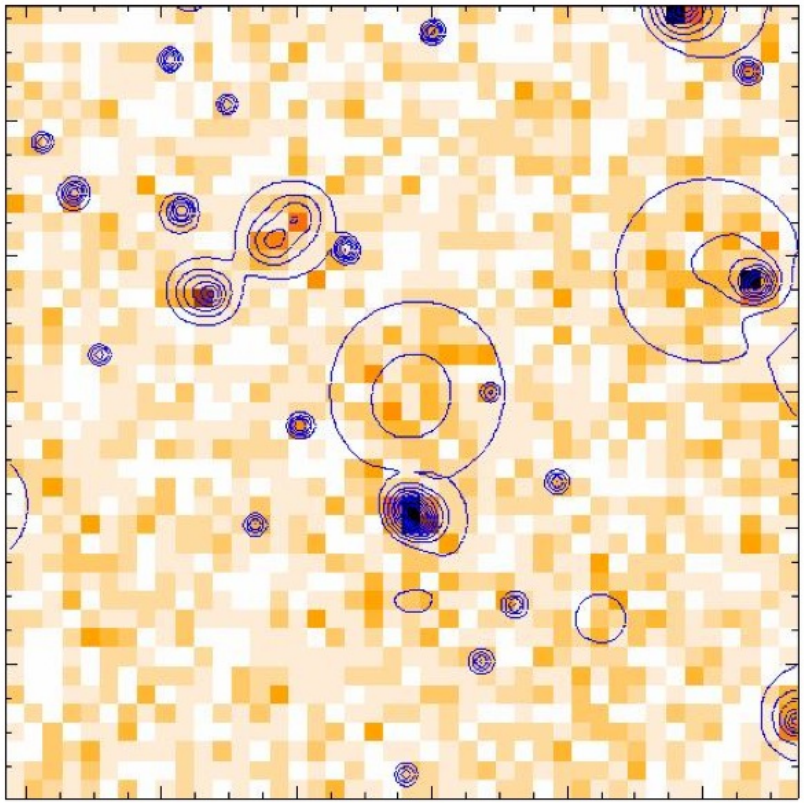
3) Distant clusters

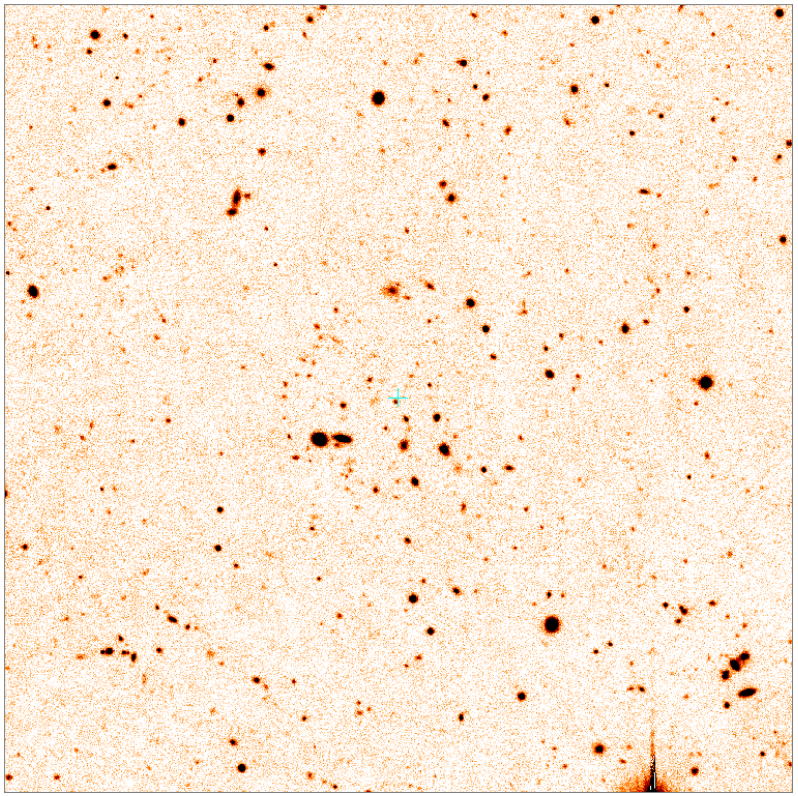
- 10 ks XMM are enough to detect a Coma cluster at z = 2.
- 1-2 C1 clusters per deg^2 beyond z>1

- 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

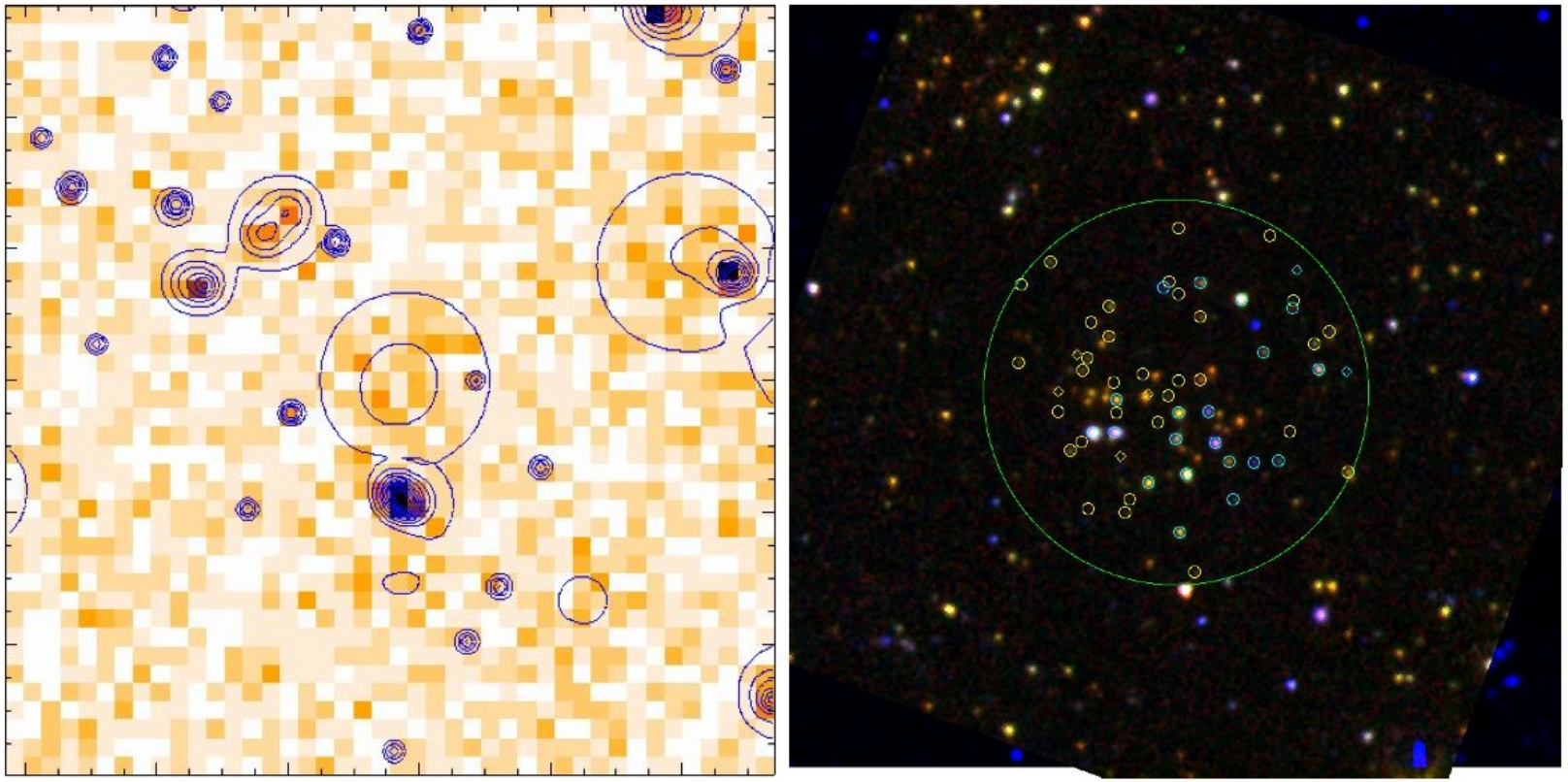
ID_1762





A distant candidate at z ~ 1.5

ID_1762



I 3.6 μm 4.5 μm

2. XXL : an overview

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 3.9 Ms of already existing data

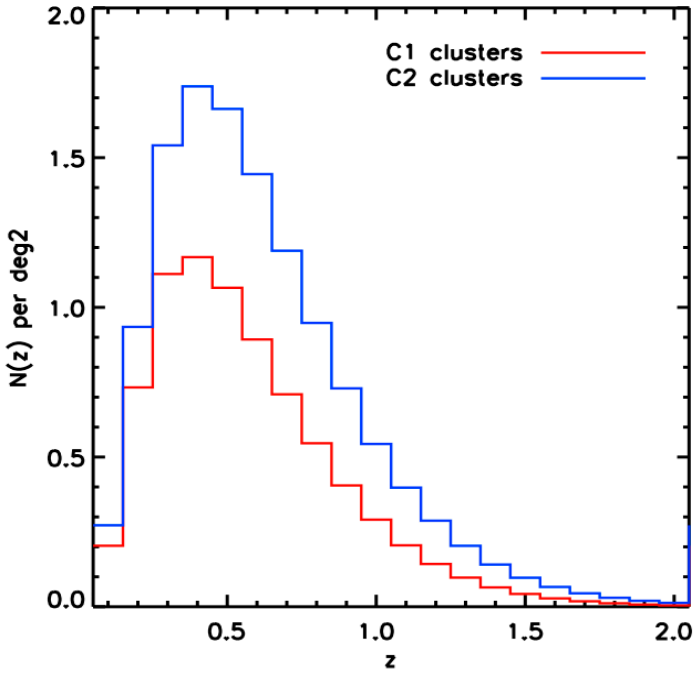
- Design driven by: the equation of state of the dark energy from clusters of galaxies

- 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

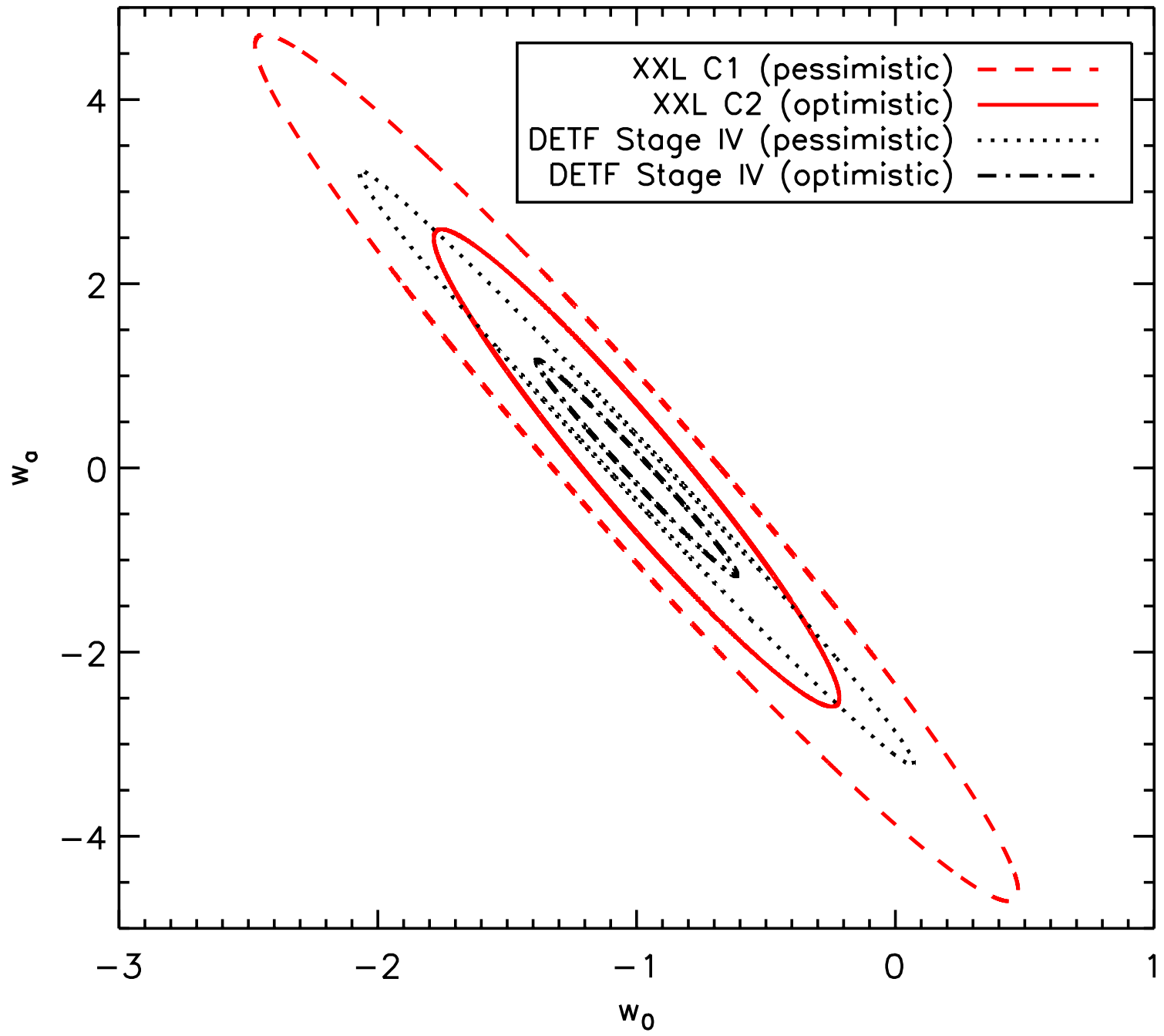
Selection	Redshift range	dn/dz + Planck	dn/dz + ξ + Planck
C1 (pessimistic)	$0 < z < 1$	2.77 / 5.98	**0.97 / 3.08**
C2 (optimistic)	$0 < z < 2$	1.14 / 2.44	**0.55 / 1.70**

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

AGN ‘hot topics’

Specific to XXL

Some 500 X-ray AGNs/deg2

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

Cluster ‘hot topics’

Specific to XXL

- The DE equation of state
- The group population at z~0.3-0.5
- 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

Focus on clusters for the rest of the talk

Legacy, from 2016 on

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

Current status

- **A large international consortium**: some 100 Co-Is
  - 19 countries
  - ~ 1/3 postdoc
  - 12 PhD students

- **XMM AO-10 observation performed** between May 2011 and May 2013. All reduced (F. Pacaud)
- Good overall data quality:
  - Less than 20% of the area significantly affected by flares
  - 20 pointings will be re-observed in 2014

- **Detection statistics,** to date:
  - Some 400 clusters
  - Some 21 500 (10 000) AGNs detected in the soft (hard) band

The associated imaging programmes

Instrument/Programme	Field	Bands	Coverage (for survey-type)	Type	Status
MegaCam at CFHT / CFHTLS	N	u,g,r,i,z	larger than XXL	E-S	C
HSC at Subaru	N	g,r,i,z,y	larger than XXL	PI-S	OG
Spitzer / SWIRE	N	3.6, 4.5, 5.8, 8.0, 24, 70, 160 μm	10 deg^2	E-S	C
Spitzer	N	3.6, 4.5, 5.8, 8.0 μm	16 deg^2	PI-S	C
VISTA VIDEO	N	Z, Y, J, H, Ks	4.5 deg^2	E-S	OG
WIRCAM at CFHT / MIRACLES	N			E-S	C
WIRCAM at CFHT	N	J, H, Ks		PI-S	OG
HAWKI at VLT/ *clusters*	N+S			PI-T	OG
HERSCHEL HERMES	N	70, 100, 160, 250, 350, 500 μm	9.3 deg^2	E-S	C
Blanco Telescope / BCS	S	g,r,i,z	larger than XXL	PI-S	C
DES	S	g,r,i,z,y	larger than XXL	E-S	OG
deep DECam survey	S	g,r,i,z	25 deg^2	PI-S	C
VISTA	S	K	larger than XXL	E-S	OG
Spitzer / SSDF	S	3.6, 4.5, 5.8, 8.0 μm	larger than XXL	PI-S	C
GMRT	N	240, 619 MHz		PI-S	OG
VLA / NVSS	N	1.4 GHz	larger than XXL	E-S	C
CARMA / *clusters*	N	30, 90 GHz		PI-T	OG
ATCA	S	2.1 MHz		PI-S	
Molonglo/SUMSS	S	843 MHz	larger than XXL	E-S	C
SPT - SPT$_{pol}$	S	90, 150, 220 GHz	larger than XXL	E-S	OG
ACT - ACT$_{pol}$	N+S	150, 220 GHz	larger than XXL	PI-S	OG

Table 2. Imaging and radio data available in the XXL fields as by end of 2013. The <Type> column indicates the source of the data, E (external) , PI (XXL PI), and whether the observations are conducted in survey mode (S) or target XXL sources (T). The <Status> column indicates whether the observations are completed (C) or on-going (OG). More detailed information, maps and references are available at http://xxlmultiwave.pbworks.com.

Details at http://xxlmultiwave.pbworks.com

The associated spectroscopic programmes

Instrument/Programme	Field	Resolution	Coverage (for survey-type)	Type	Status
VIMOS / VIPERS	N	R=200	16 deg^2	E-S	OG
AAOmega / GAMA field G02	N	R=1400	23.5 deg^2 overlap with XXL	E-S	OG
SSDS DR9	N	R=1300-3000	larger than XXL	E-S	C
WHT / *detailed velocity mapping of groups*	N+S	R=800		PI-T	OG
NTT / *clusters*	N+S	R=300		PI*-T	OG
FORS2 / *clusters*	N+S	R=600		PI*-T	OG
AAOmega / *clusters + AGNs*	S	R=1400	25 deg^2	PI-S	OG

Table 3. Spectroscopic data available in the XXL fields as by end of 2013. The <Type> column indicates the source of the data, E (external) , PI (XXL PI), and whether the observations are conducted in survey mode (S) or target XXL sources (T). The <Status> column indicates whether the observations are completed (C) or on-going (OG). The * stands for ESO Large Programme. More detailed information, maps and references are available at http://xxlmultiwave.pbworks.com.

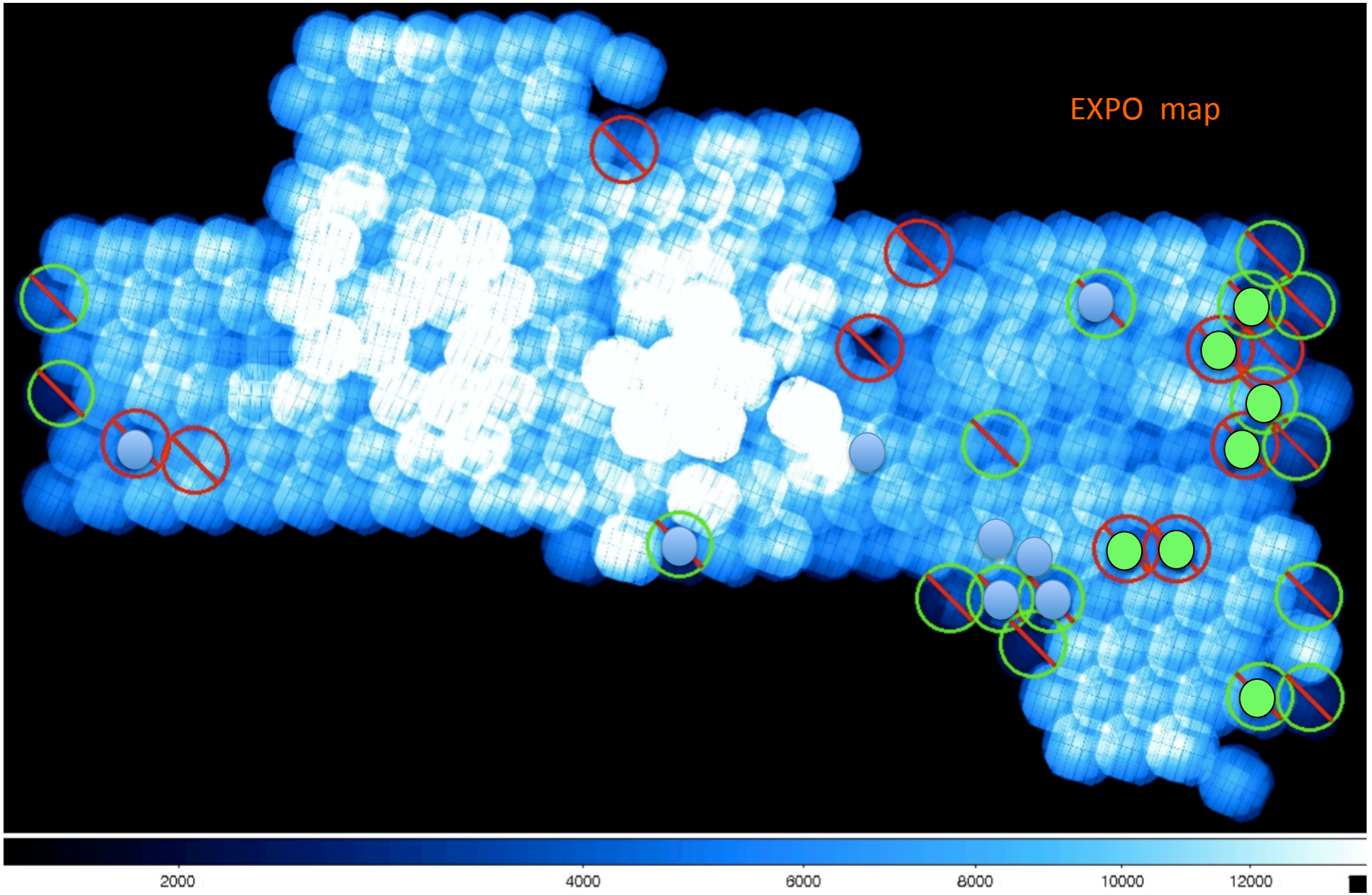
Details at http://xxlmultiwave.pbworks.com

3. XXL : preliminary results

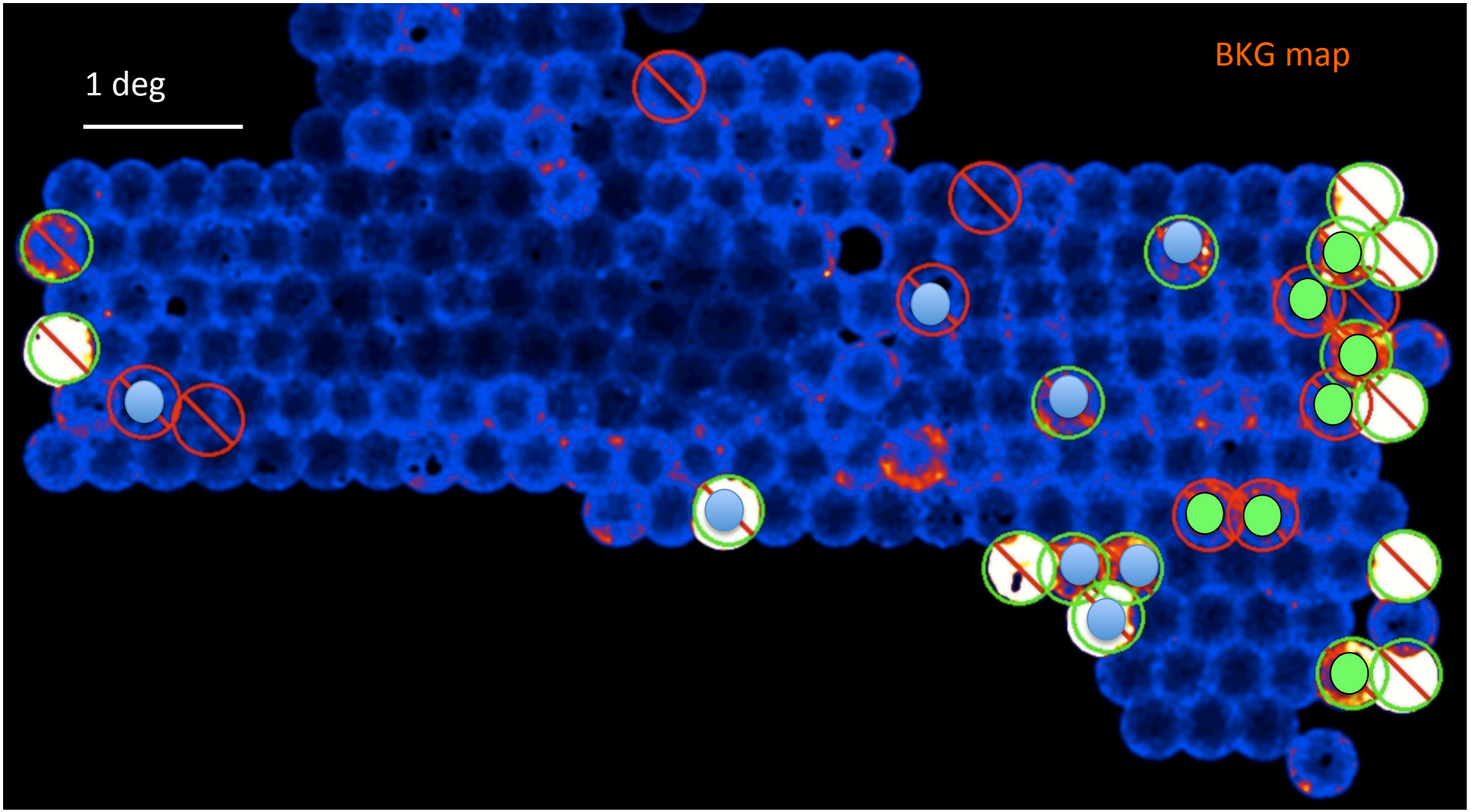
Current sensivity maps

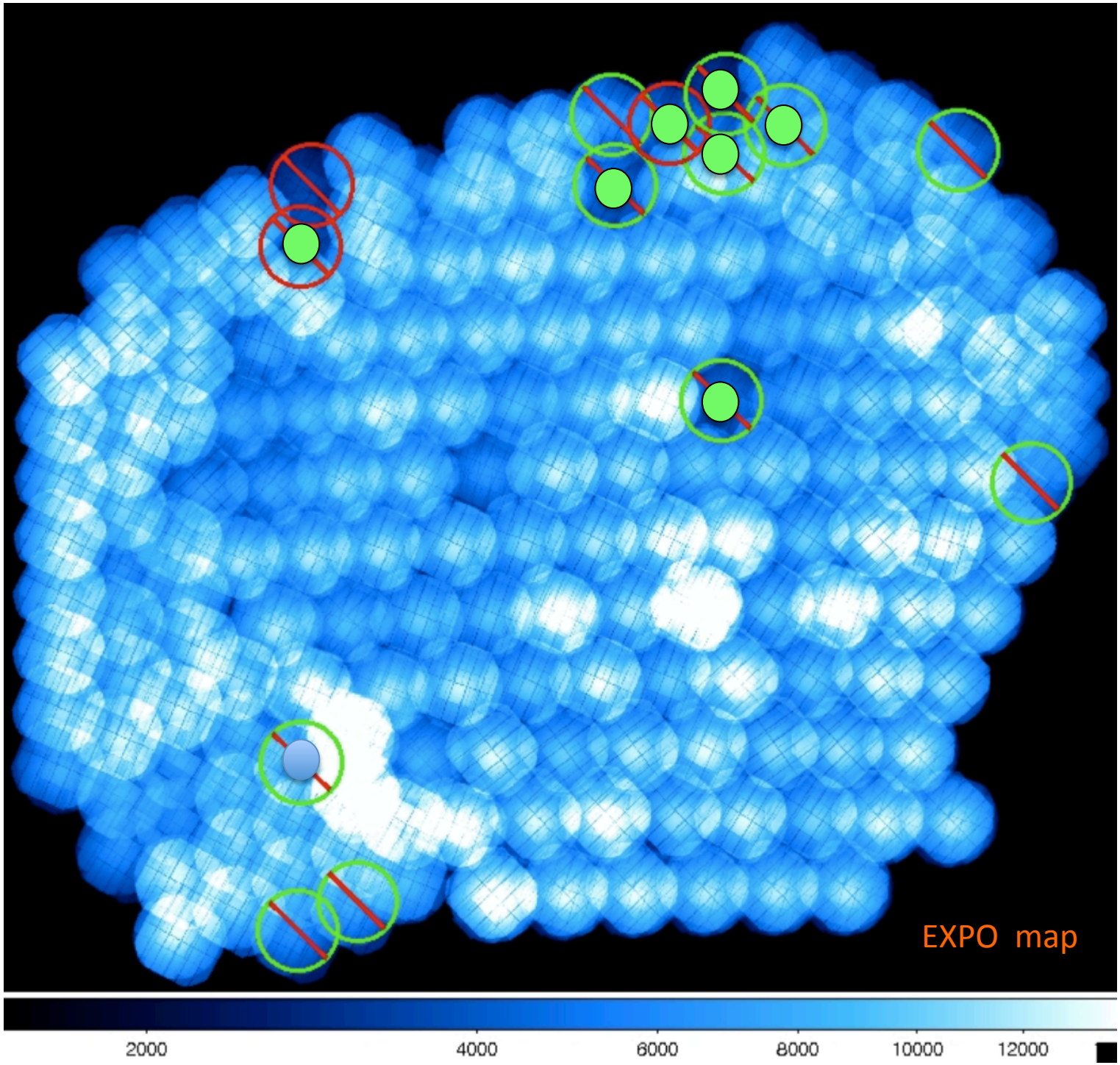
- **A010 observations (3 Ms) were performed between May 2011 and May 2013**
- **In total: 331 sky positions**
- Overall good quality (less than 20% 'bad' observations)
- AO13 allocation (260 ks) to fill the 'gaps' in the sensitivity maps
  - done
  - still to be done

XXL-N

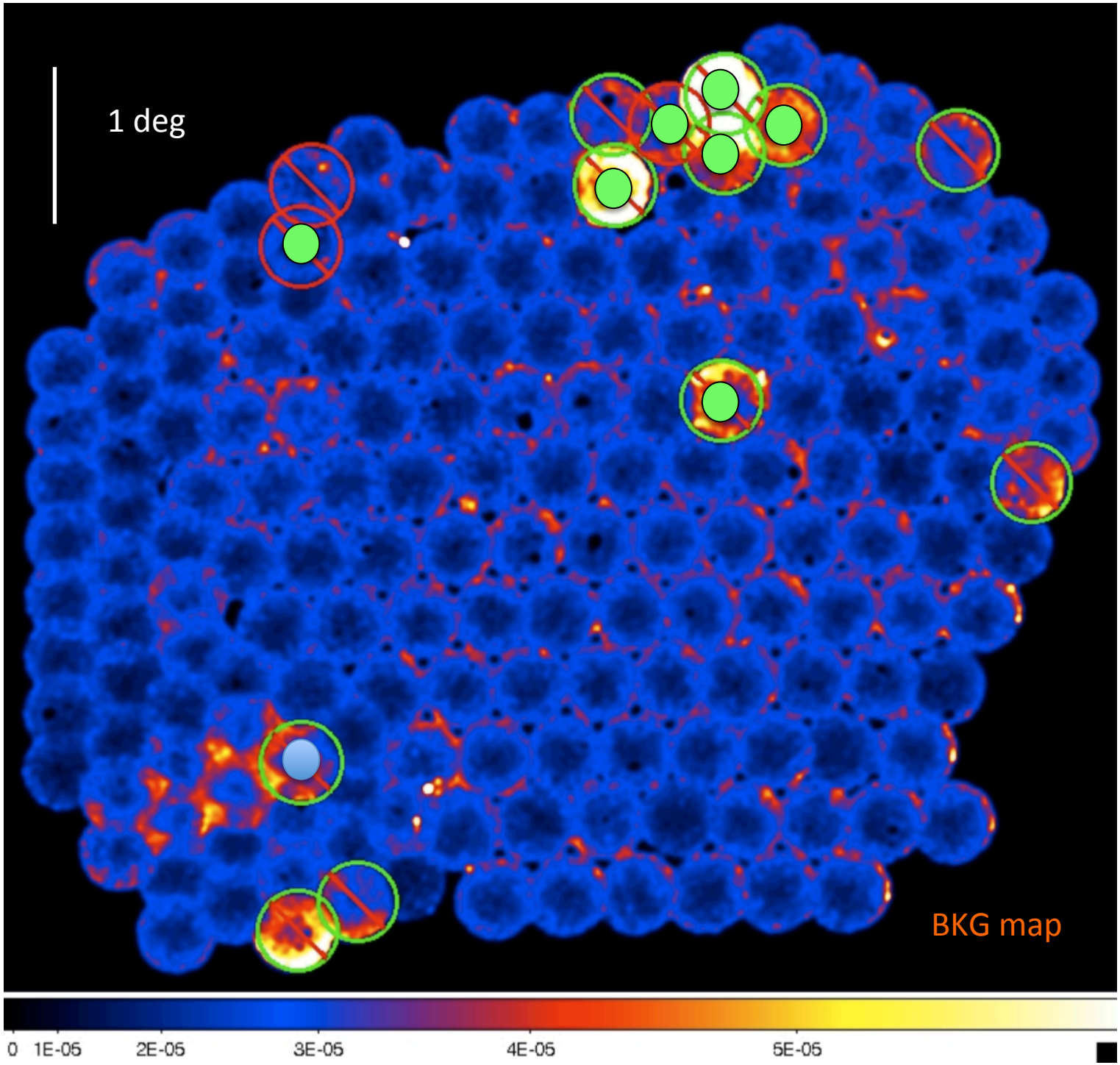


XXL-N





XXL-S



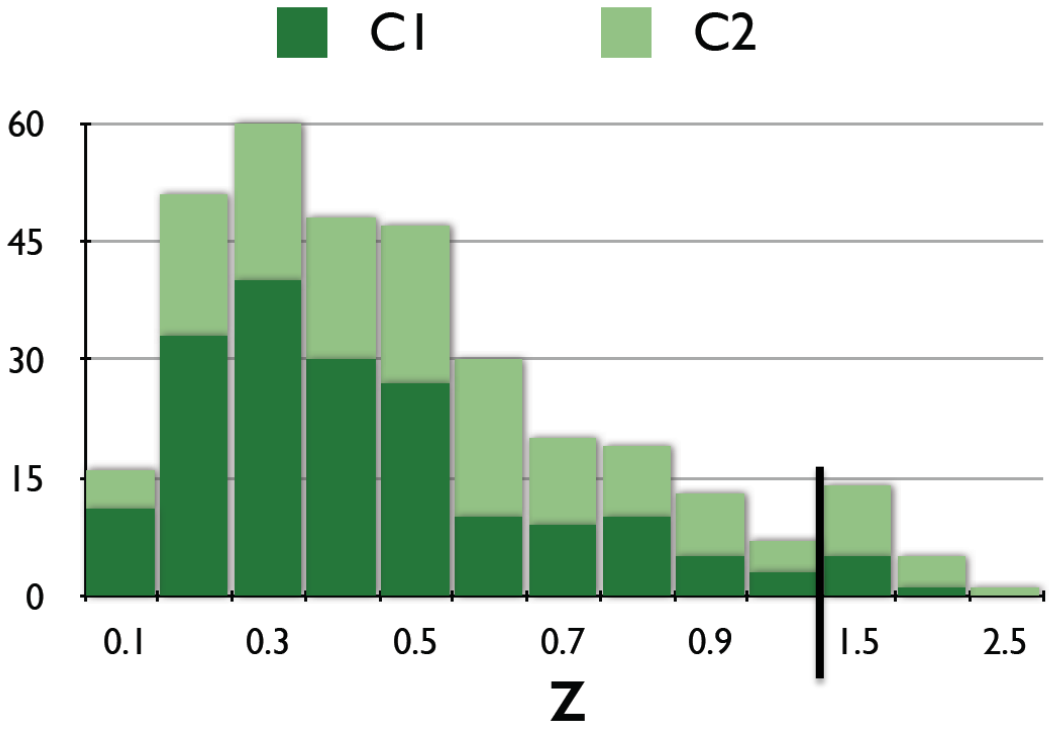
XXL-S

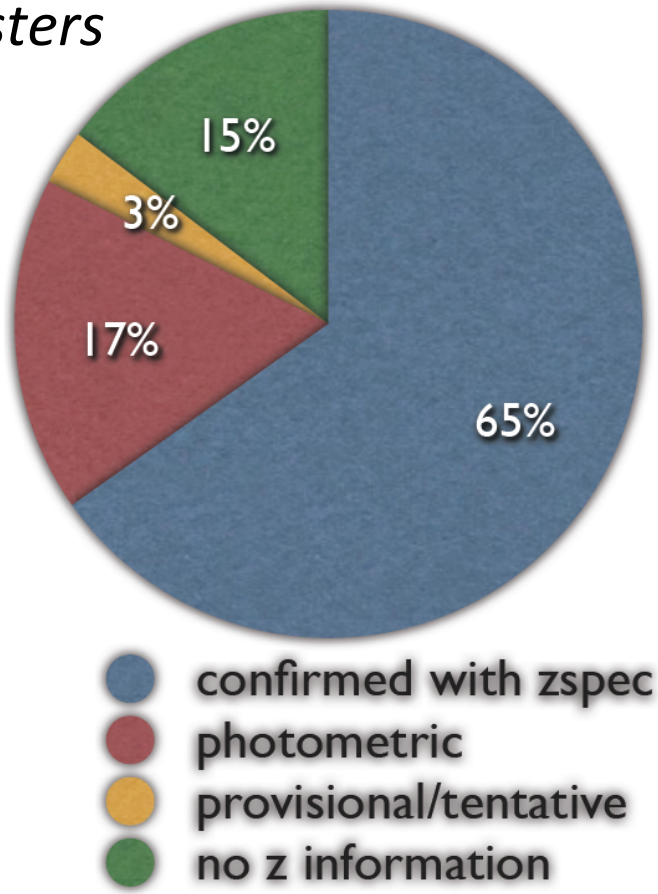
Current cluster redshift distribution

Redshifts from our own ESO LP, WHT, AAT campaigns and GAMA

ESO LP half way !

388 clusters





First publications… soon

- Samples of **brightest 100 clusters** and **1000 AGNs**
  - Fluxes, redshifts, luminosities, masses, SEDs
  - Cluster evolution, cosmology and AGN LSS

- First XXL publication:

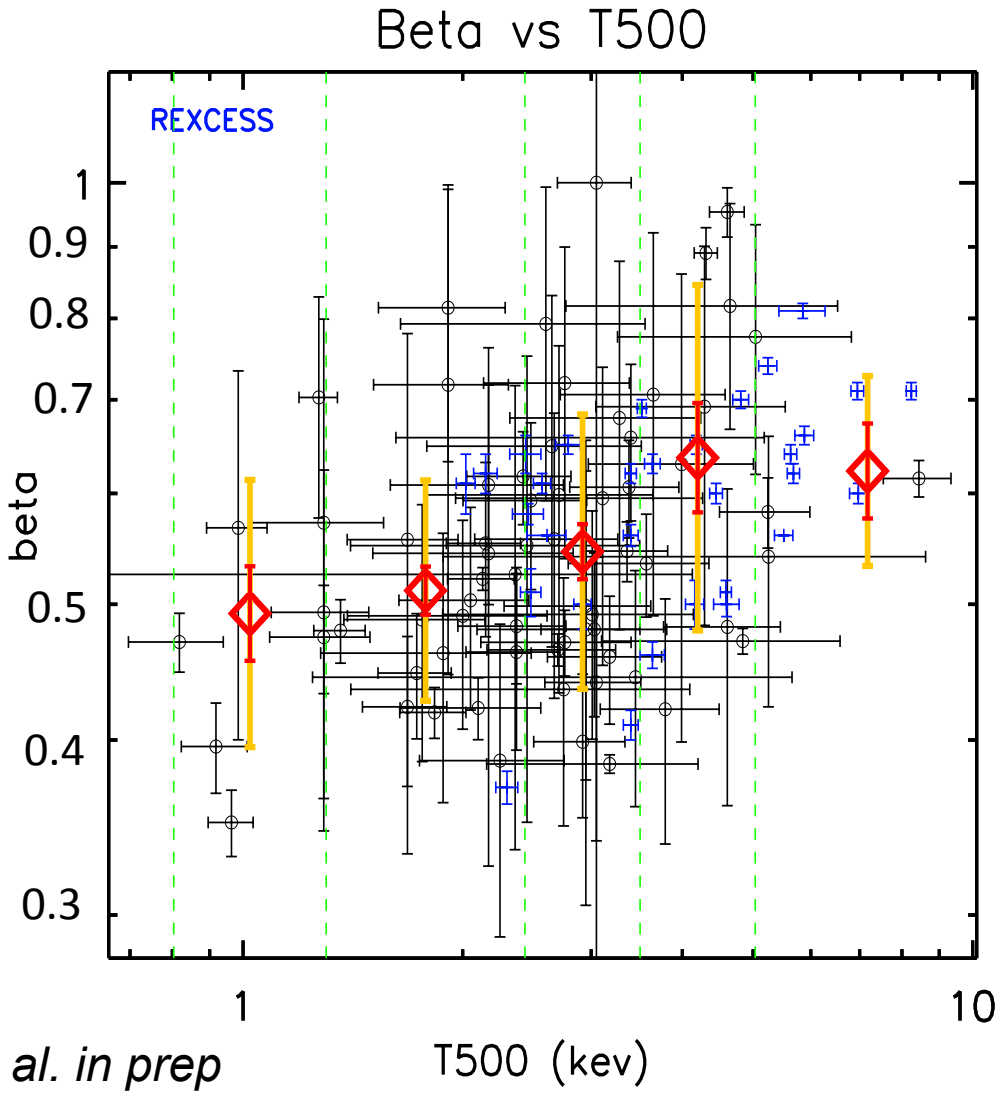
The most distant X-ray/S-Z cluster detected at : z = 1.9 (*Mantz et al 2014*)

- In parallel, X-ray/optical cluster matching using the SDSS and the XMM archive clusters (XCLASS)

  Sadibekova et al 2014 => increase low-z statistics

Evolution of the outer slope with temperature

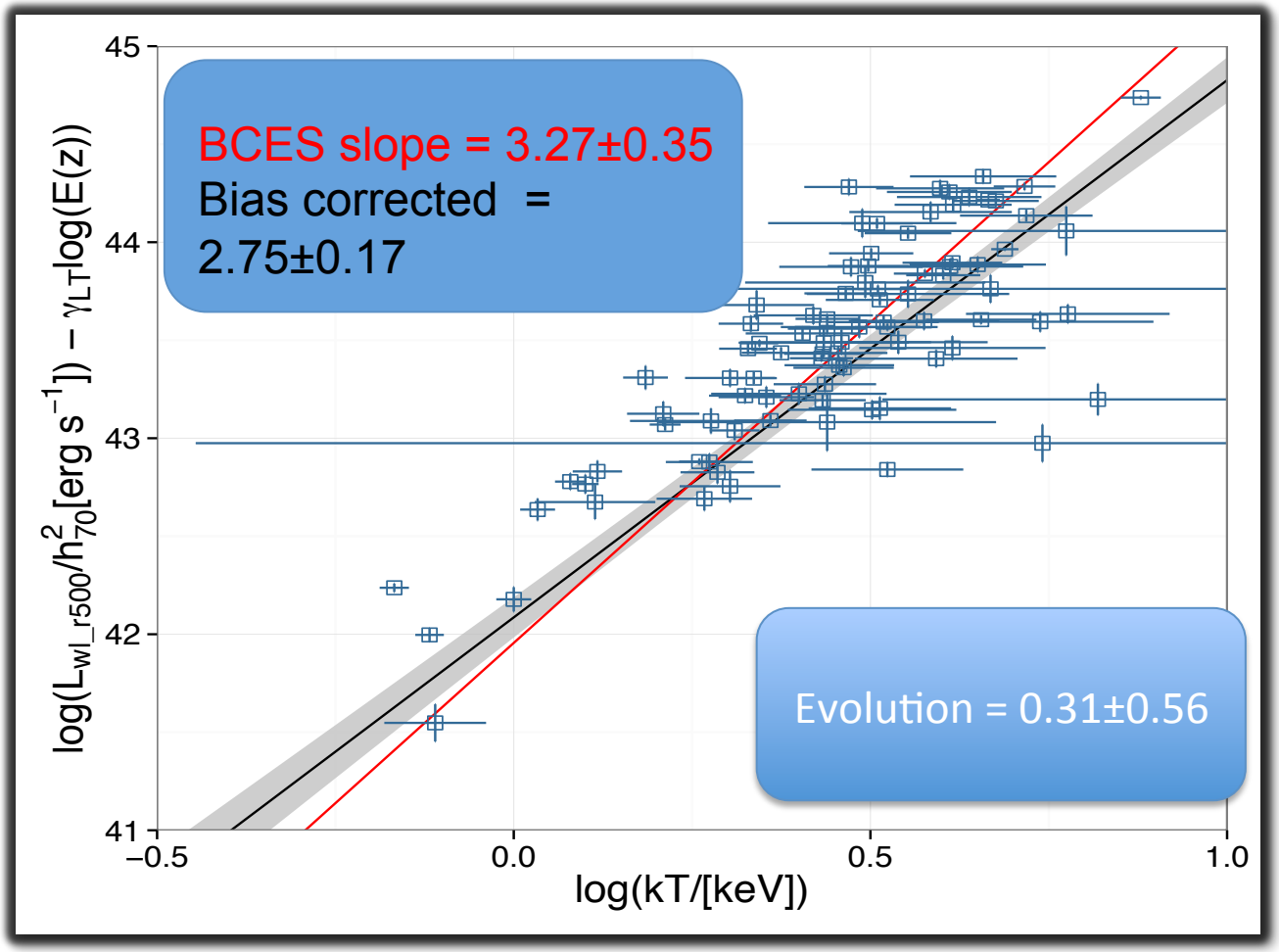
- Partial correlation attributes the correlation to be due to the temperature (Spearman rank test gives a null probability of ~ 0.01)



Democles et al. in prep

Talk by Jessica Democles Wednesday afternoon

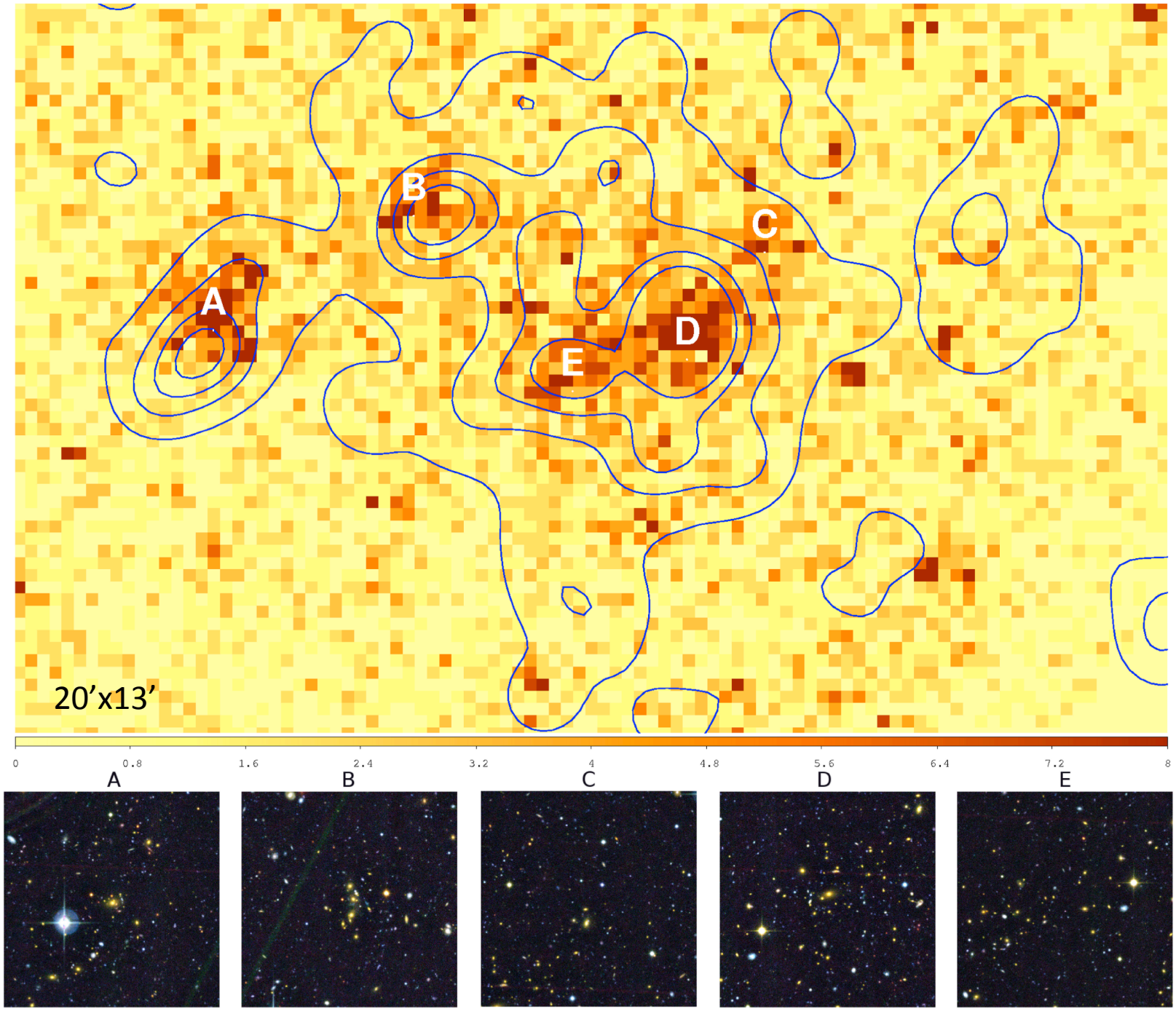
L_X – kT Relation (selection effects corrected)



Talk by Paul Giles
Thursday afternoon

Giles et al. in prep

Discovery of a super group at z=0.5



XMM + CARMA z~ 1.9

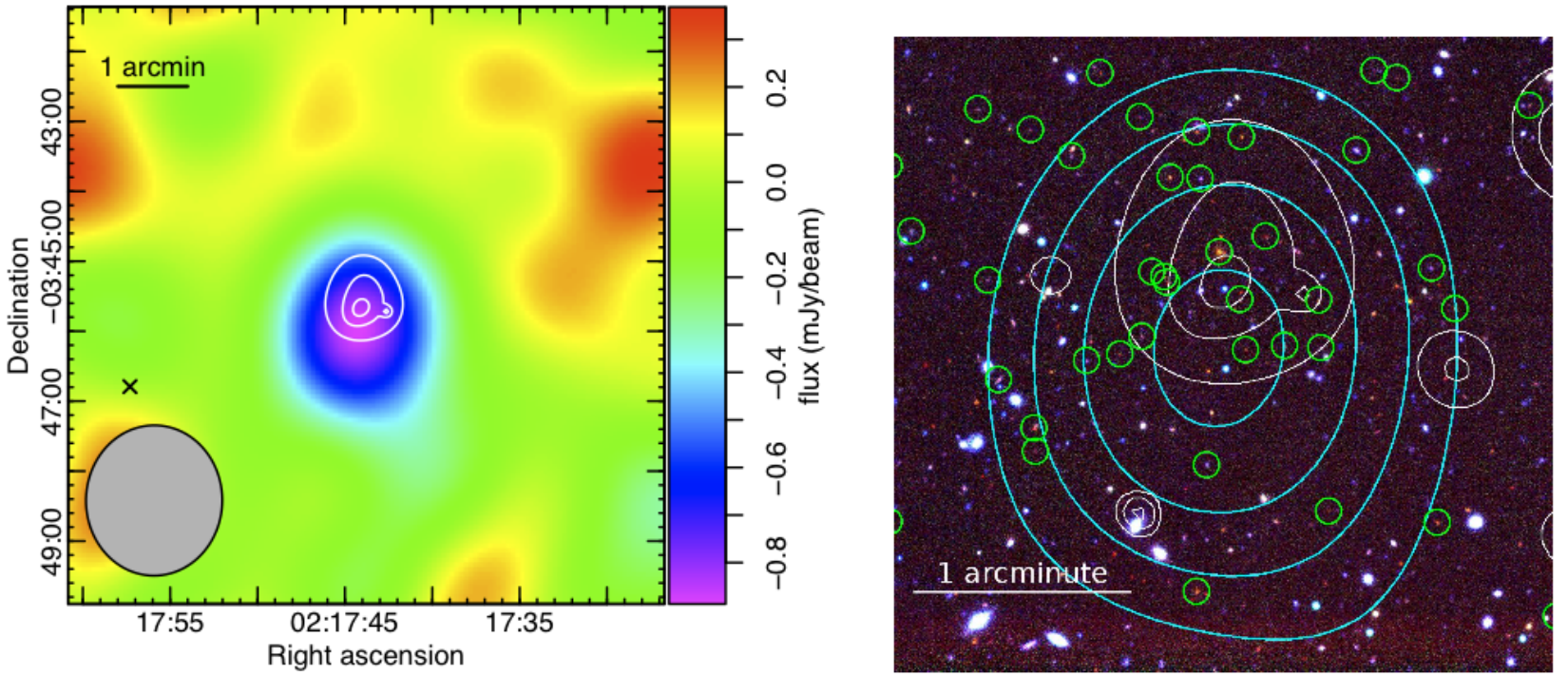
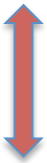


Figure 1. Left: Short-baseline (uv radii $< 2\mathrm{k}\lambda$) 30 GHz map of XLSSU J0217−0345 after modeling and subtracting point sources and applying the CLEAN algorithm. The position of the brighter point source in Table 2 is indicated by the "×" (the other lies outside the image). White contours show the extended X-ray emission associated with the cluster detection. The gray ellipse in the lower-left corner shows the FWHM synthesized beam. Right: iJK image, with X-ray (white) and SZ (blue) contours overlaid. The SZ contours correspond to −2.5, −3.5, −4.5, and −5.5 times the rms noise level of the short-baseline map. Galaxies with photometric redshifts in the range $1.7 < z < 2.1$ are circled in green.

Mantz et al 2014

Associated numerical simulation programme

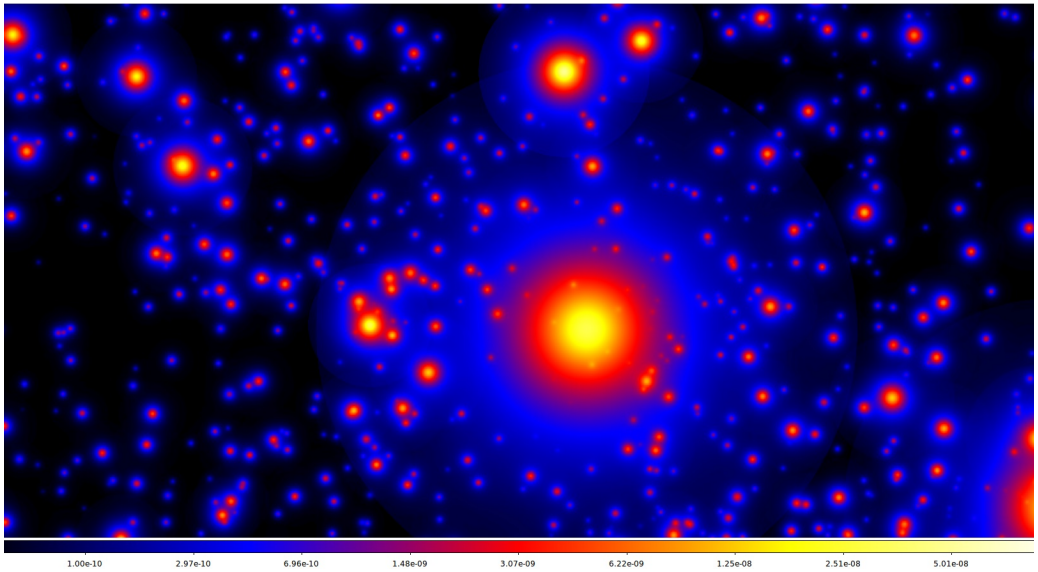
- Test the impact of cluster physics (luminosity, size) on the selection function



- Test the realism of the input cluster physics

- Test combined cluster mass measurements (X-ray, optical, S-Z, lensing)

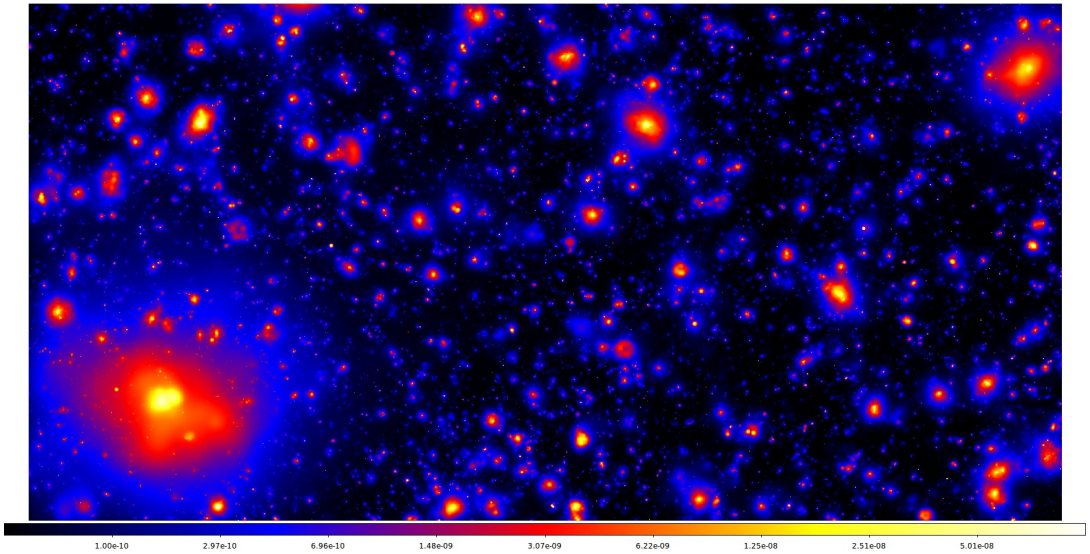
Projected XXL simulated lightcones



Evrard & Co
N-Body + template

Quick and very large realisations

Folded into an XMM image simulator: PSF, BKG, energy, detector topology



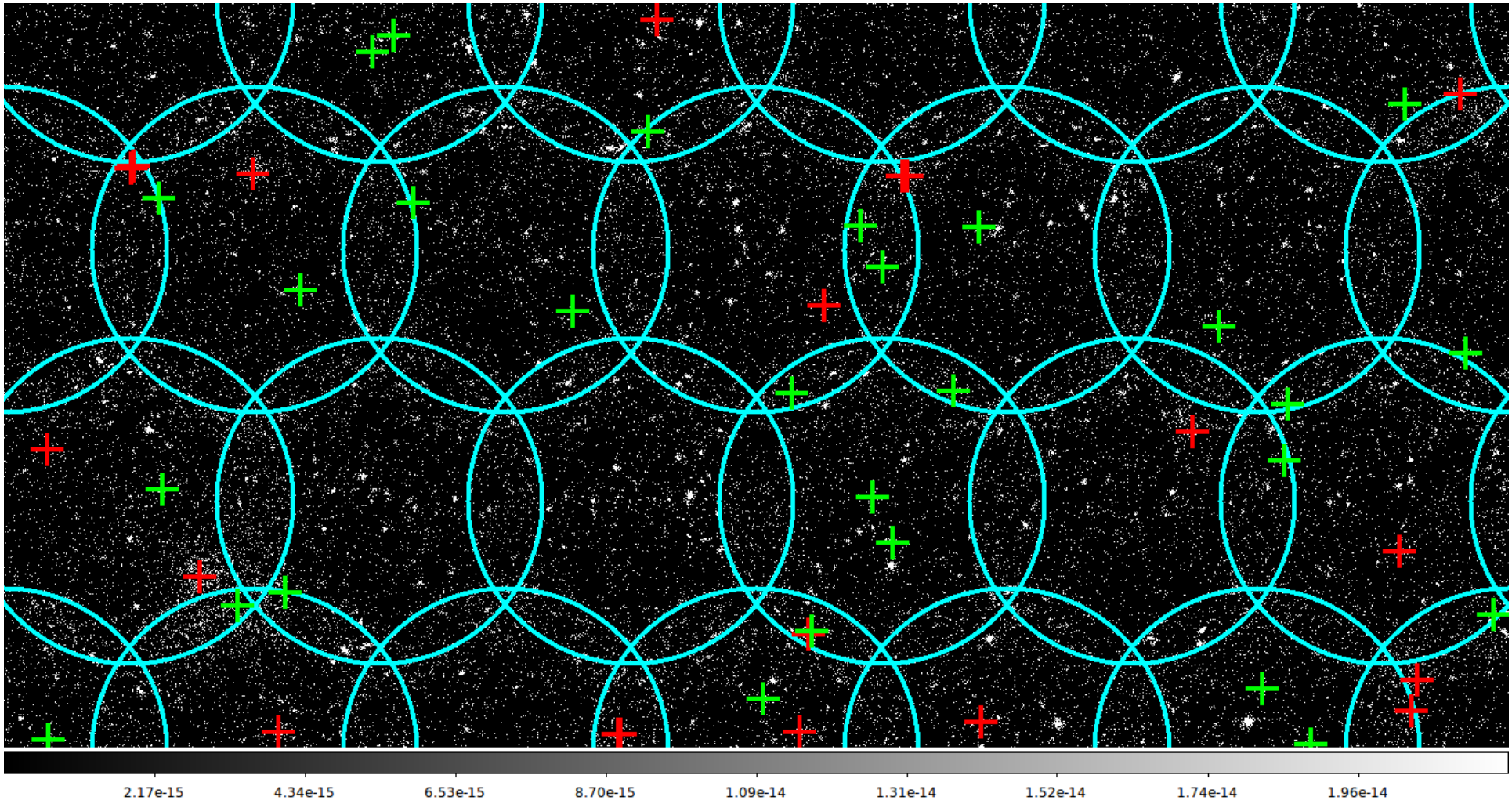
McCarthy & Co
Hydrodynamic

Refined gaz +AGN physics

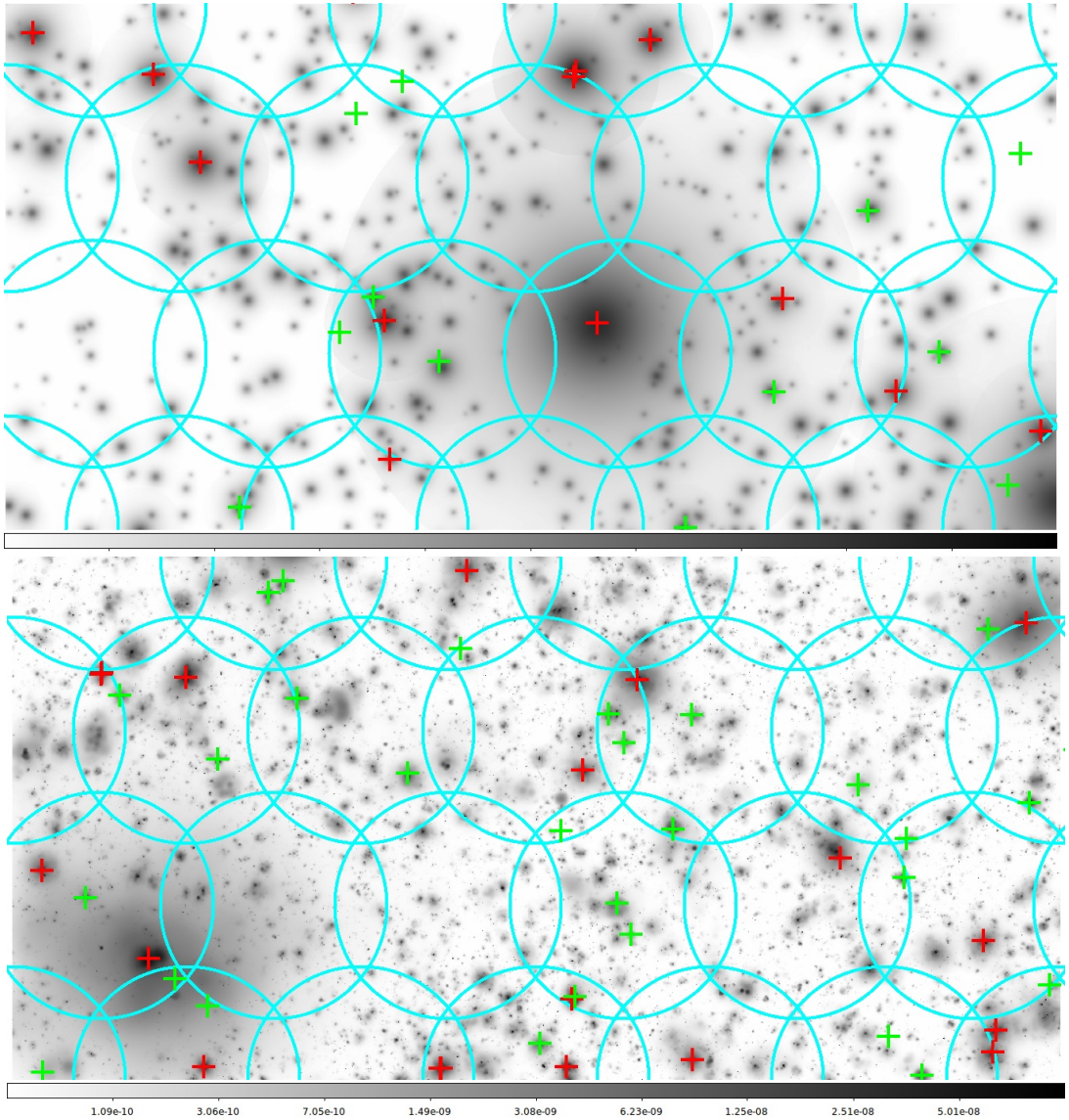
Displayed images: 1x2 deg^2 cut-out

‘Real simulated’ XMM moscaic

C1 clusters C2 clusters



Detected clusters



C1 clusters

C2 clusters

Faccioli, Sauvageot et al in prep

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

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

Life was simpler in the past...

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

PIERO ROSATI,[1,2,3,4] ROBERTO DELLA CECA,[5] COLIN NORMAN,[2] AND RICCARDO GIACCONI[1]

Received 1997 August 7; accepted 1997 October 28; published 1997 November 14

ABSTRACT

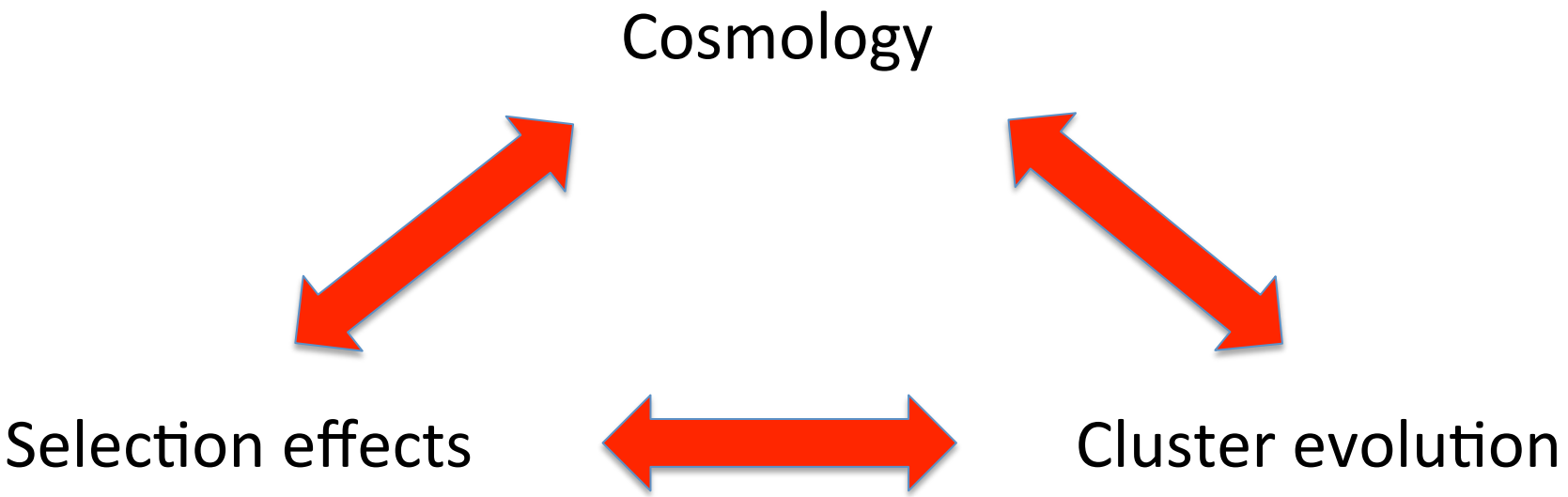
We present the X-ray luminosity function (XLF) of the *ROSAT* Deep Cluster Survey sample over the redshift range 0.05–0.8. Our results are derived from a complete flux-limited subsample of 70 galaxy clusters, representing the brightest half of the total sample, which have been spectroscopically identified 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 magic triangle

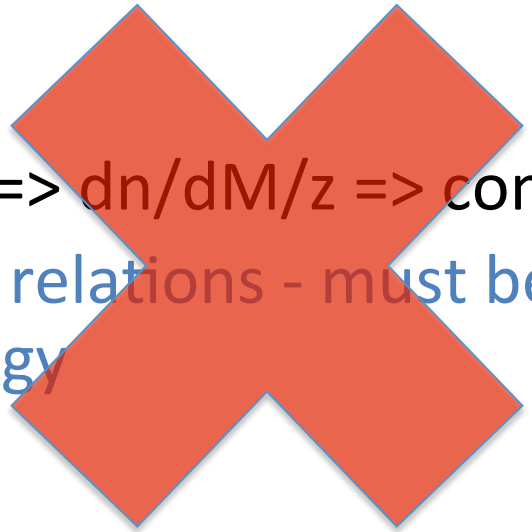


Modern cluster cosmology

- **Usual route:**

Flux, Temp => Mass => dn/dM/z => compare with theory

Masses - and scaling relations - must be computed for each tested cosmology



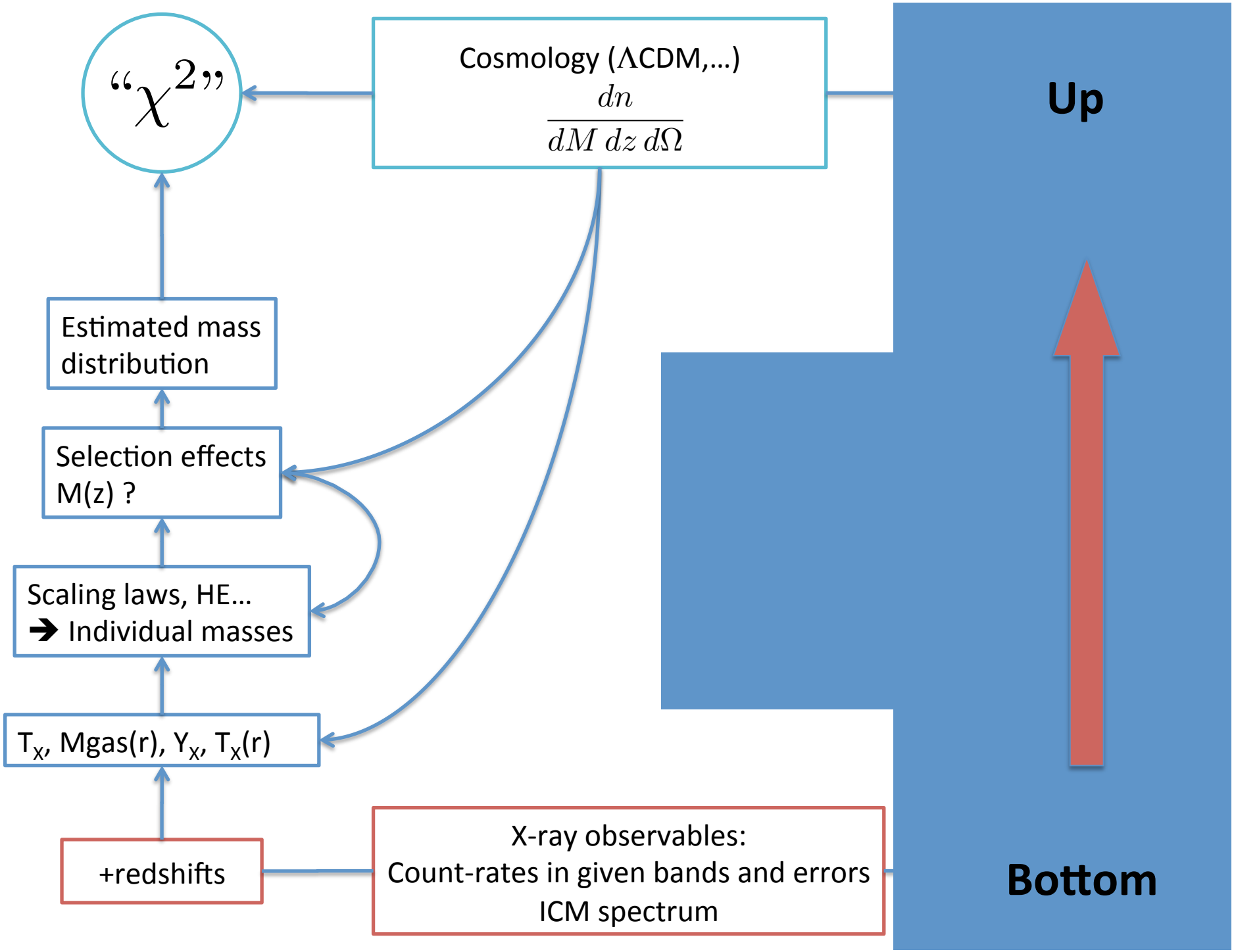
- **Quick way:**

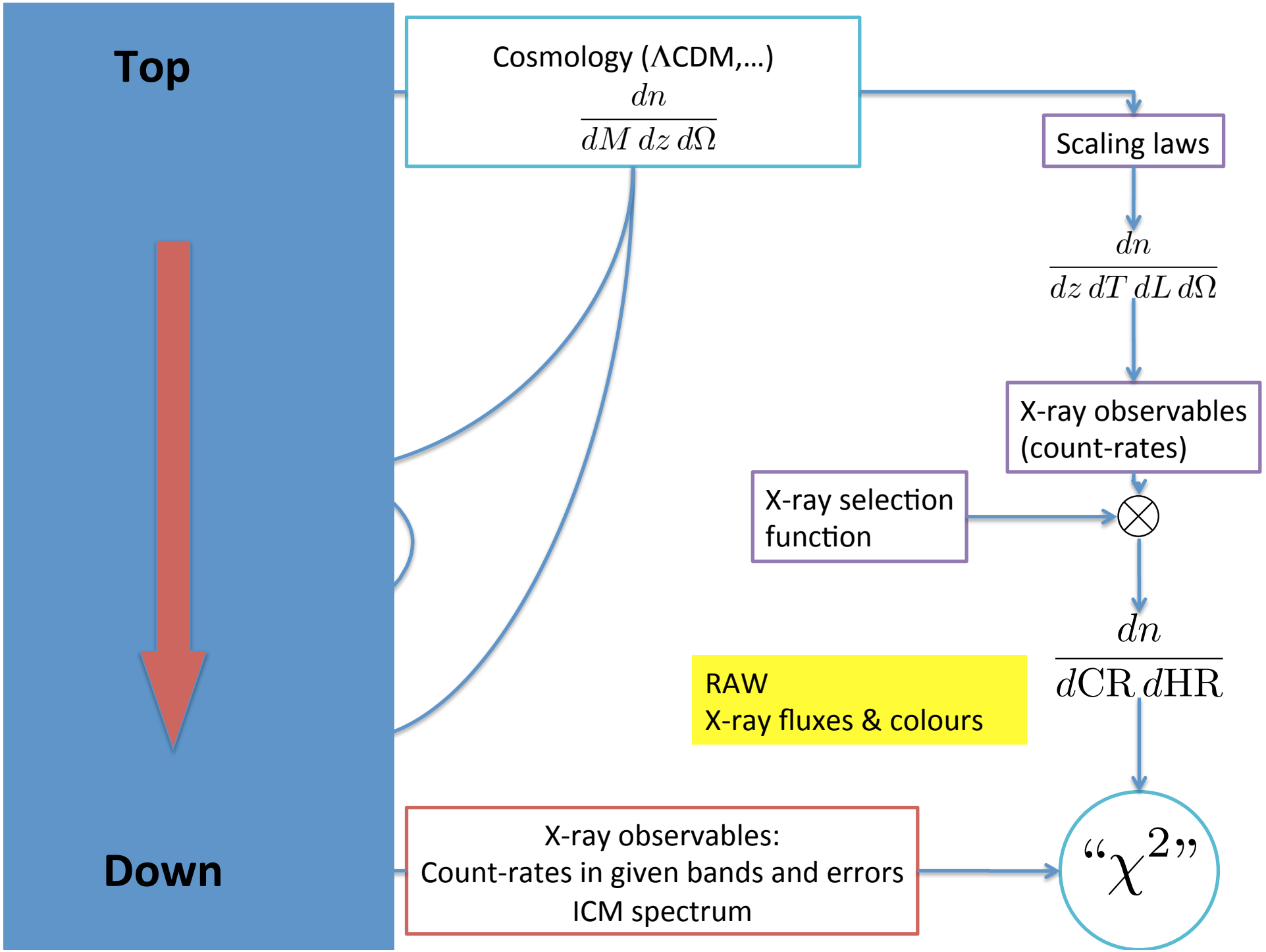
Work directly in the observed parameter space

➔ Predicted X-ray colour-magnitude diagrams

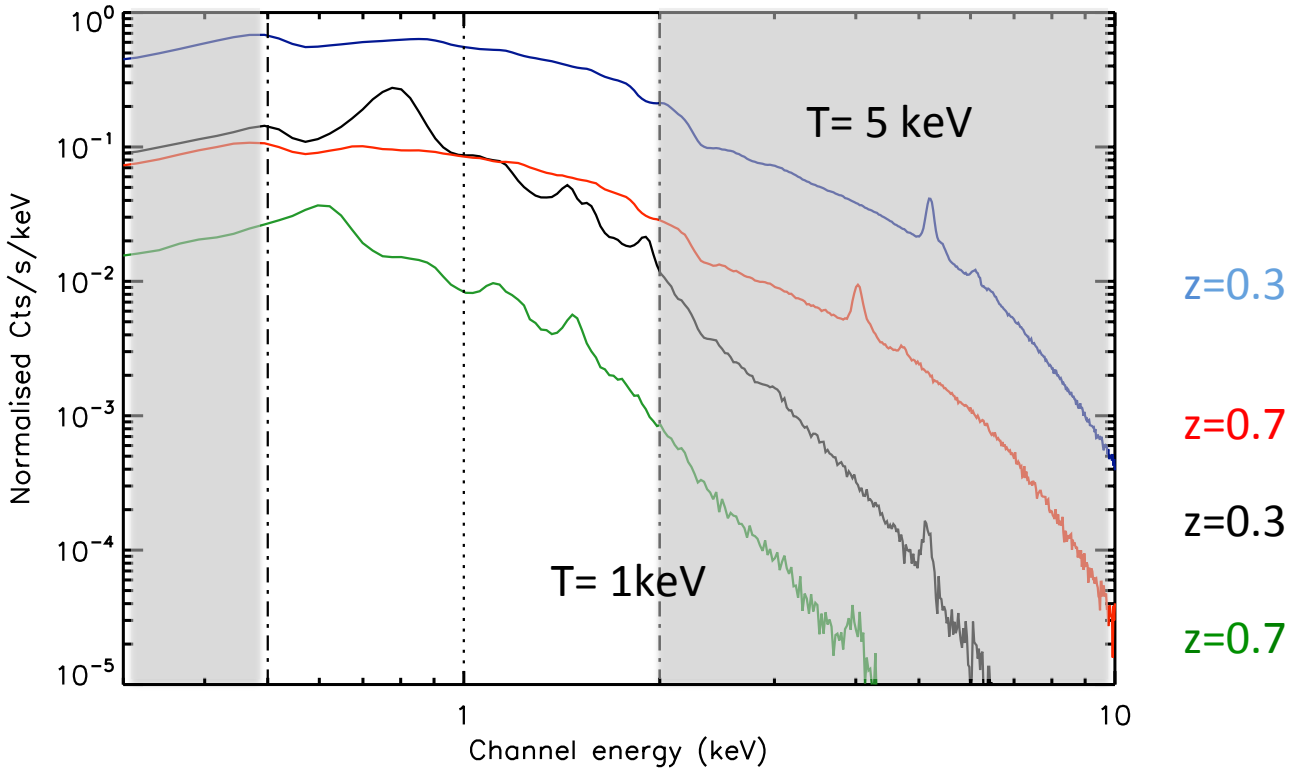
Fit simultaneously:

cosmology - cluster evolution - selection effects


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


Top
Down
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
$\frac{dn}{d\mathrm{CR}\,d\mathrm{HR}}$
RAW
X-ray fluxes & colours
X-ray observables:
Count-rates in given bands and errors
ICM spectrum
"χ^2"

- CR in [0.5-2] keV ~ Magnitude
- HR = [1-2]/[0.5-1] ~ Colour



The CR-HR distribution

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

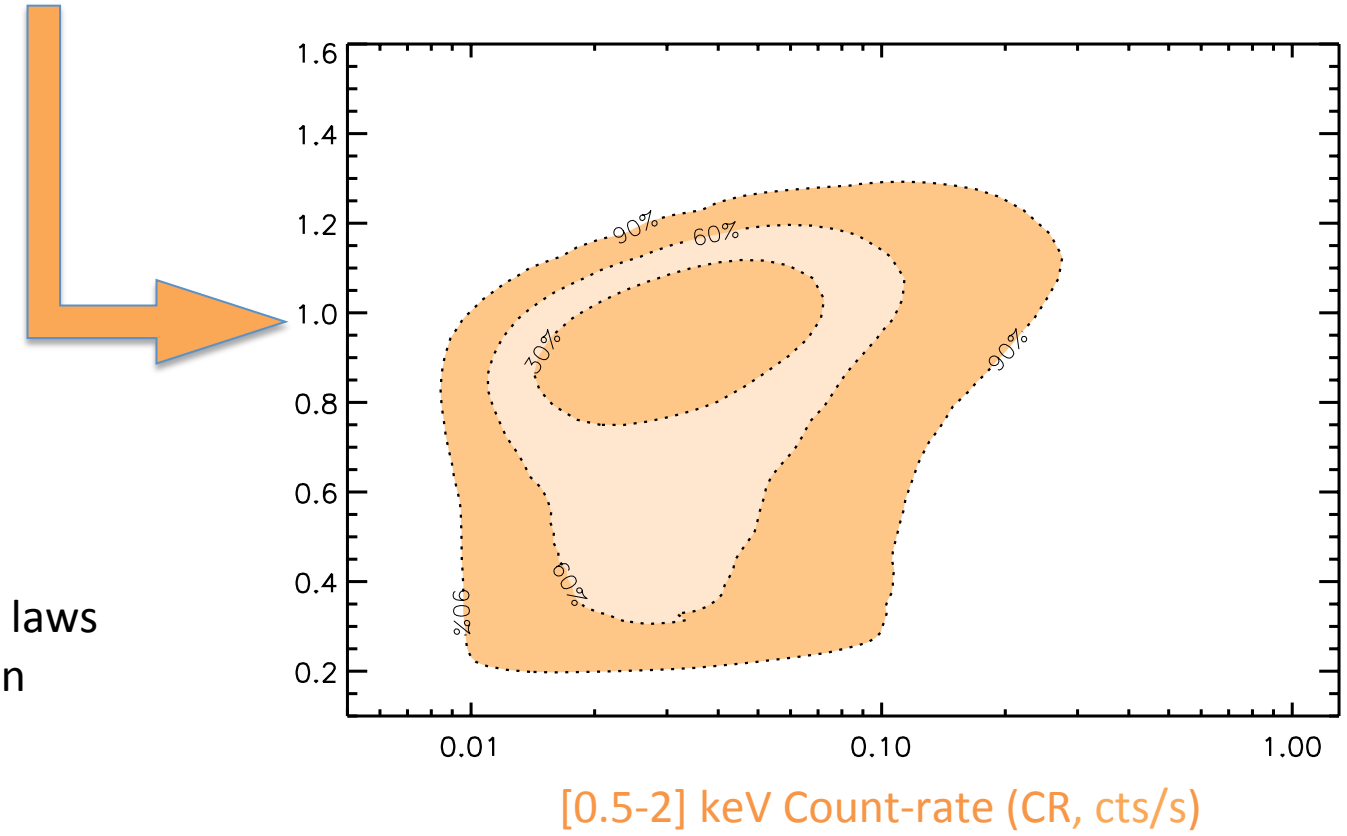
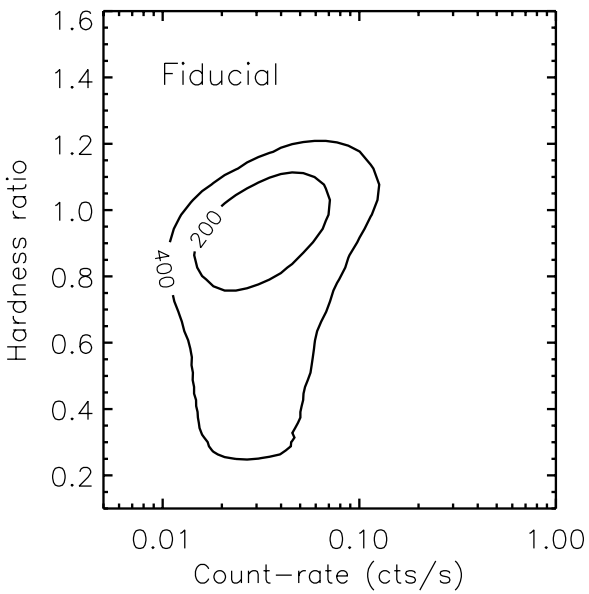


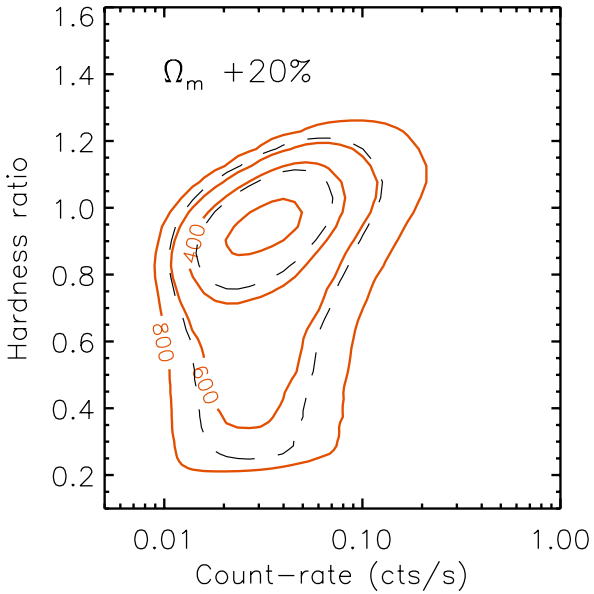
Diagram computed for :

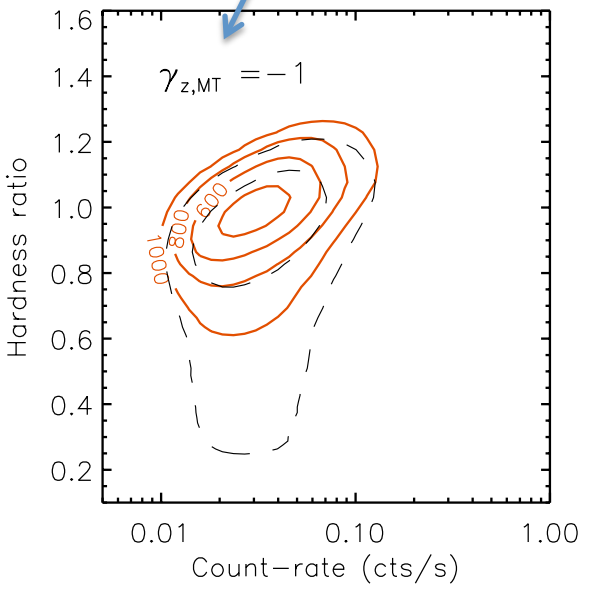
- WMAP5 cosmology
- C1 selection
- Local cluster scaling laws
- Self-similar evolution

100deg2

Non self-similar evolution



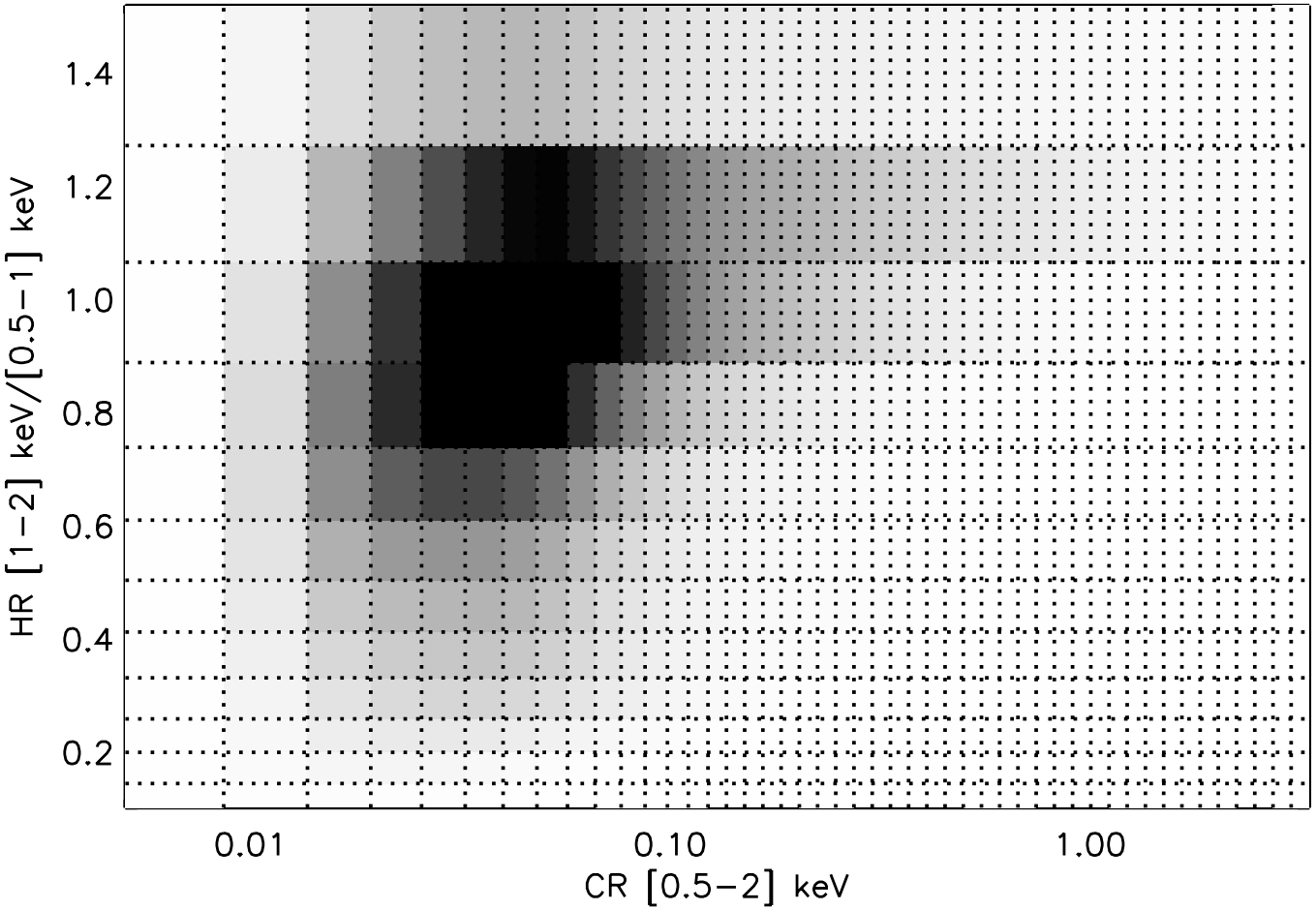




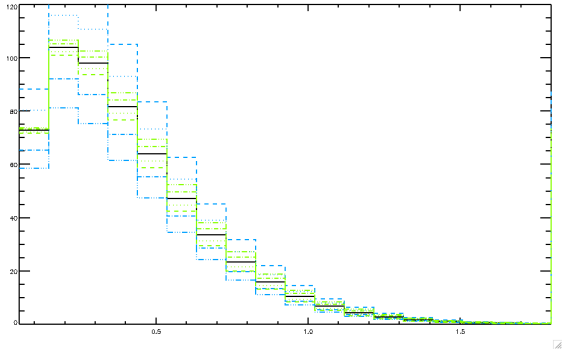
Evaluating the HR-CR method

Clerc et al 2012a, 2012b

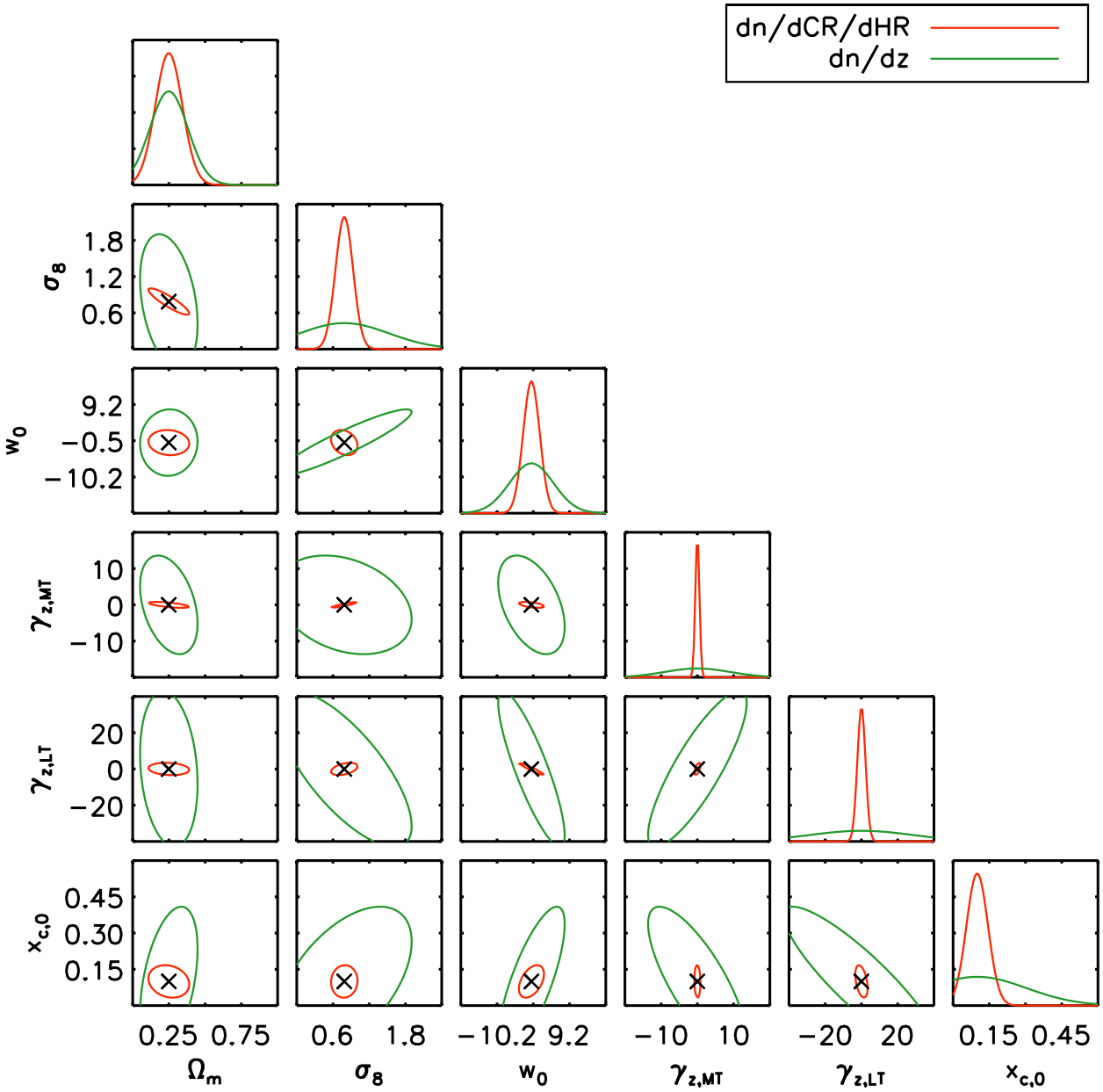
Implement realistic measurement errors



1) CR/HR vs dn/dz

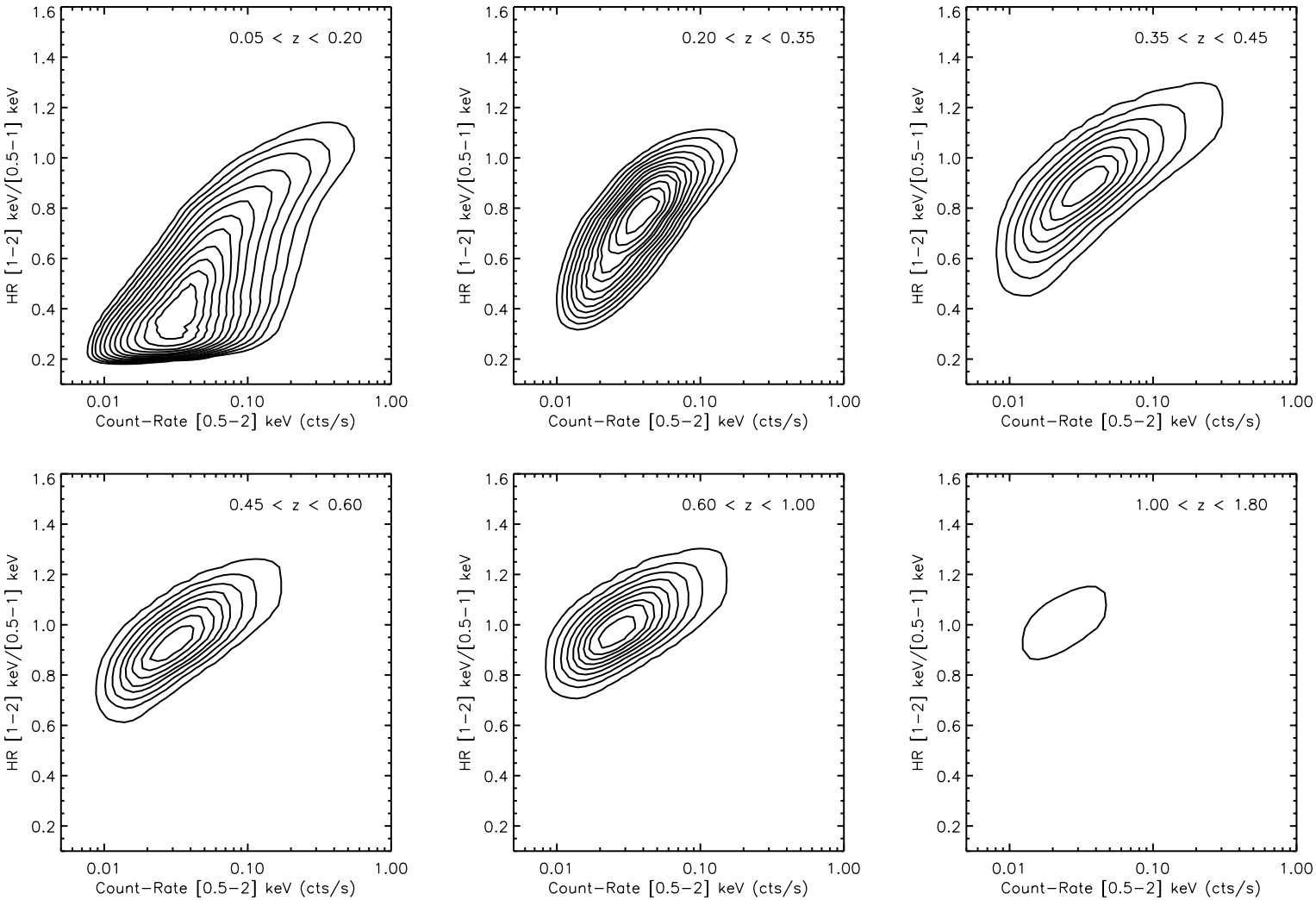


Good, but there are still dgeneracies



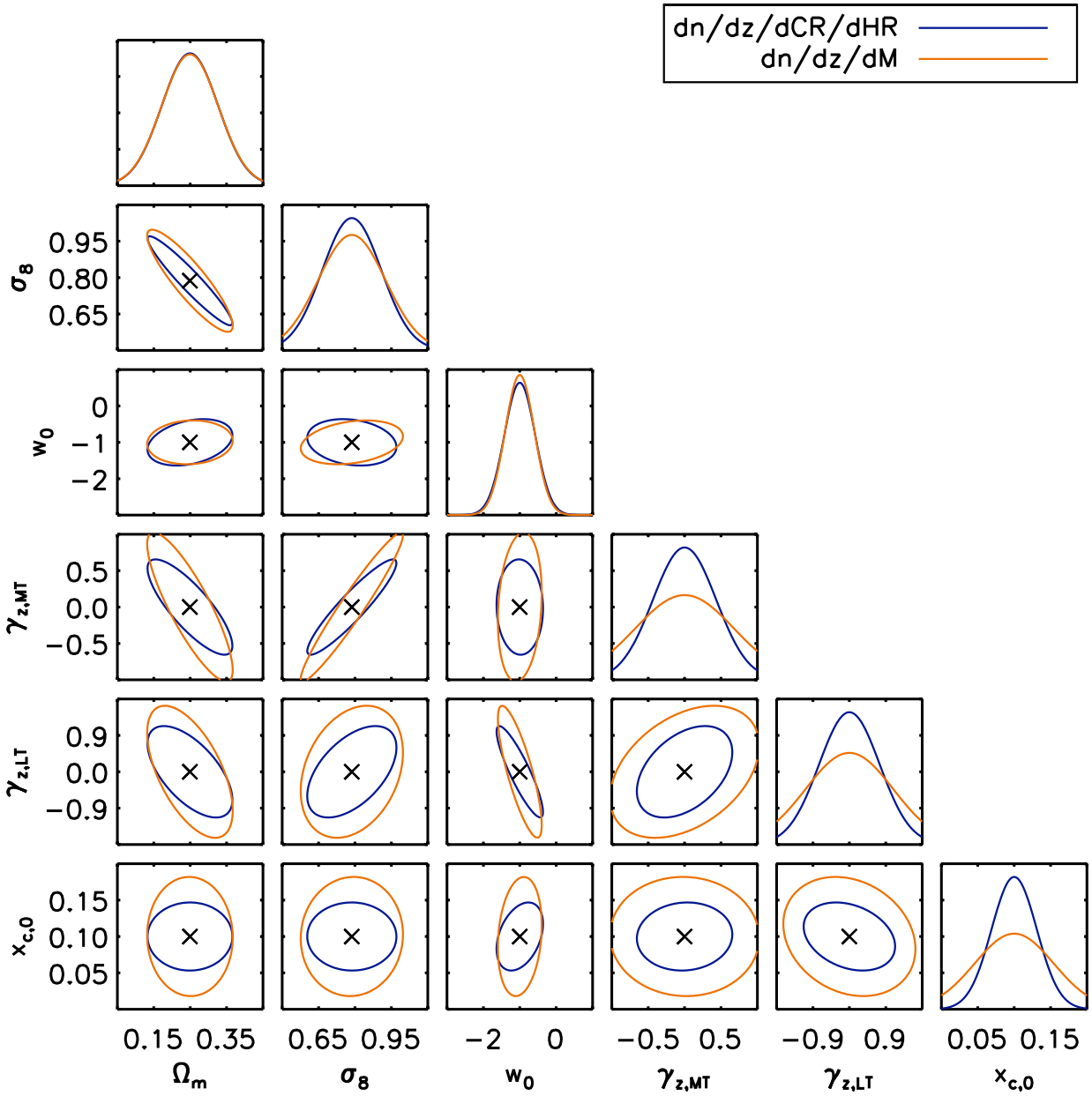
Plugging redshift information into the HR-CR diagram

➔ 3rd dimension to the diagram



With redshifts
(photo-z are sufficient)

2) CR-HR-dz
vs
N(M, z)



See poster by
Nicolas CLERC: H02

CONCLUSION

XXL = DE (almost) **now… !**
+ many other things

XMM is a wonderful survey instrument!

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**

- **Evaluate 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