Distant X-ray Luminous Galaxy Clusters from the XMM Archive

Possibilites and Limitations

Rene Fassbender (MPE)

XXL Survey Workshop
April 2008

Outline

i. The XMM-Newton Distant Cluster Project

ii. XMM Archive Potential

iii. Distant Cluster Finding in X-rays

iv. **Optical Follow-up**

v. Conclusions

i. **The XMM-Newton Distant Cluster Project**

ii. XMM Archive Potential

iii. Distant Cluster Finding in X-rays

iv. Optical Follow-up

v. Conclusions

The XMM-Newton Distant Cluster Project Team

Hans Böhringer (MPE)
Rene Fassbender (MPE)
Joana Santos (MPE)
Gabriel Pratt (MPE)
Martin Mühlegger (MPE)
Piero Rosati (ESO)
Chris Mullis (U of Michigan)
Axel Schwope (AIP)
Georg Lamer (AIP)
Jan Kohnert (AIP)
Hernan Quintana (PUC)

XDCP Science Aims

Goal: ~40 z≥1 clusters

Shortterm:

- X-ray & optical studies of individual high-z clusters
- galaxy evolution

Midterm:

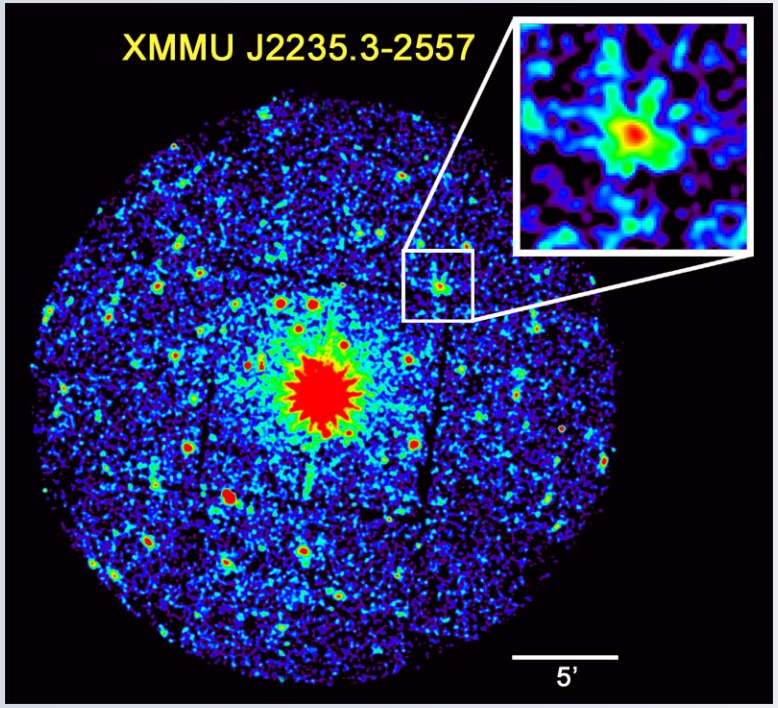
- high-z X-ray scaling relations
- combined X-ray-SZE sample studies

Longterm:

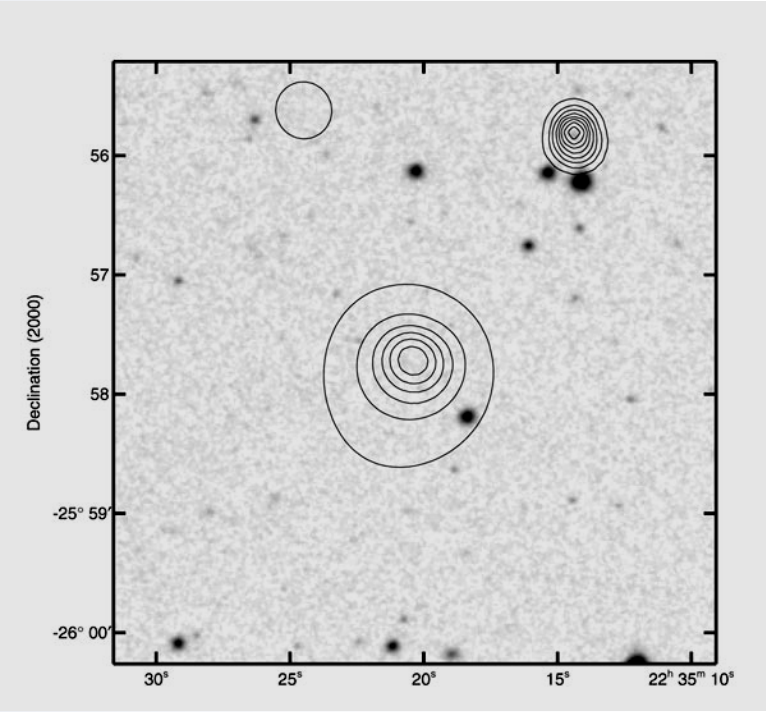
- cosmological studies
- cluster number density evolution

X-ray Selection of Distant Cluster Candidate Sources

Step 1:
detection of serendipitous extended X-ray source



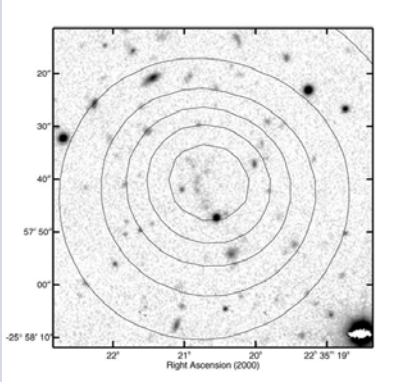
Step 2:
DSS rejection of sources with z<~0.6 counterparts



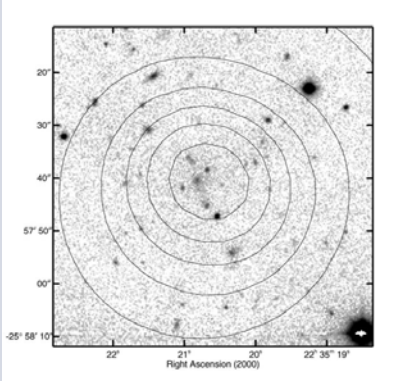
From C. Mullis

Two-band Follow-up Imaging

Step 3:
confirmation of cluster as overdensity of galaxies

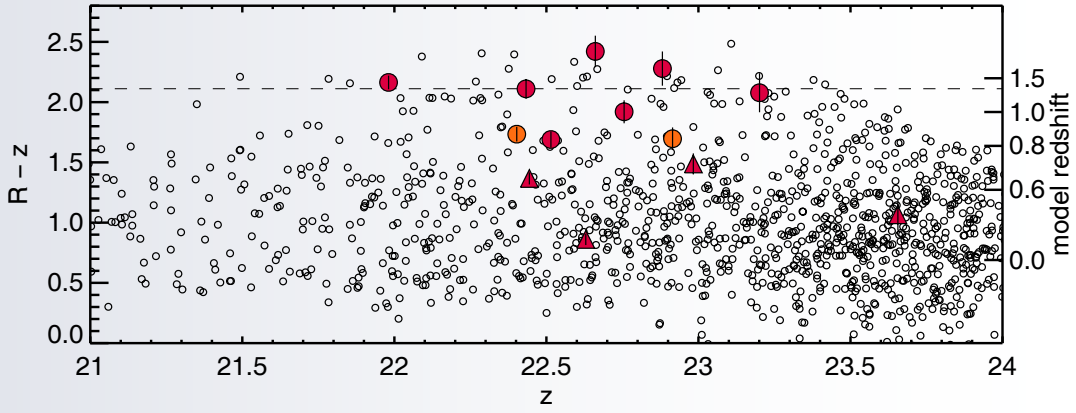


R



z

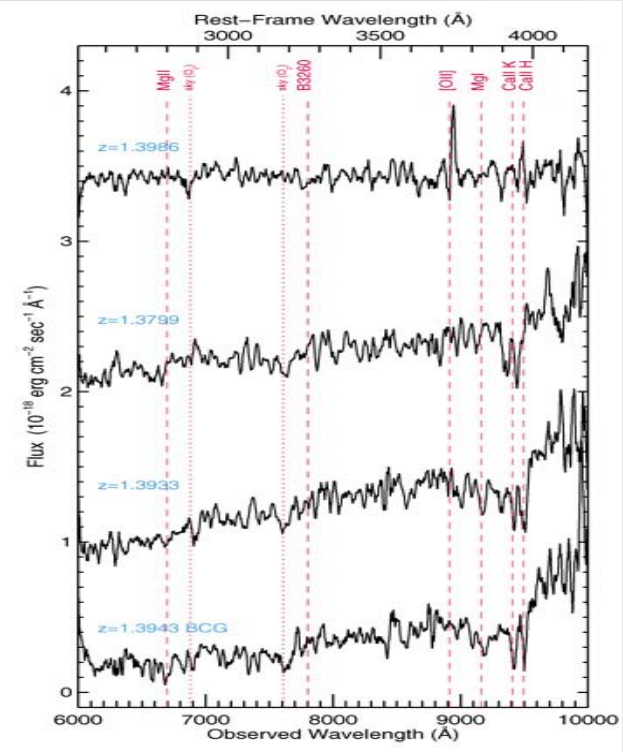
Step 4:
redshift estimate using the ‘red-sequence’ method



From C. Mullis

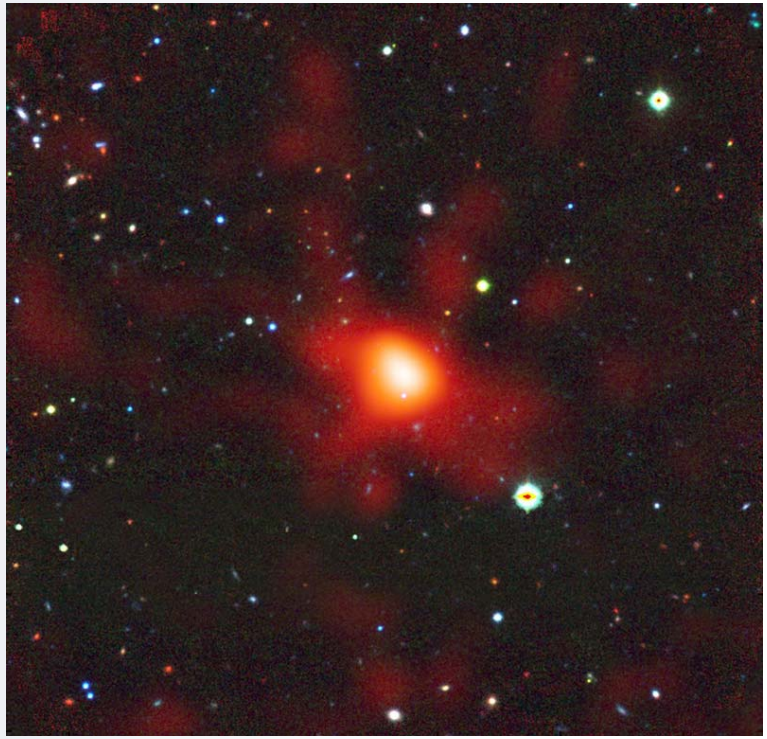
Detailed Studies

Step 5:
Spectroscopic confirmation as 3D bound object



From
C. Mullis

Step 6:
Detailed studies of most intersting objects: Rad-Xray



i. The XMM-Newton Distant Cluster Project

ii. **XMM Archive Potential**

iii. Distant Cluster Finding in X-rays

iv. Optical Follow-up

v. Conclusions

XMM Archive & Field Selection

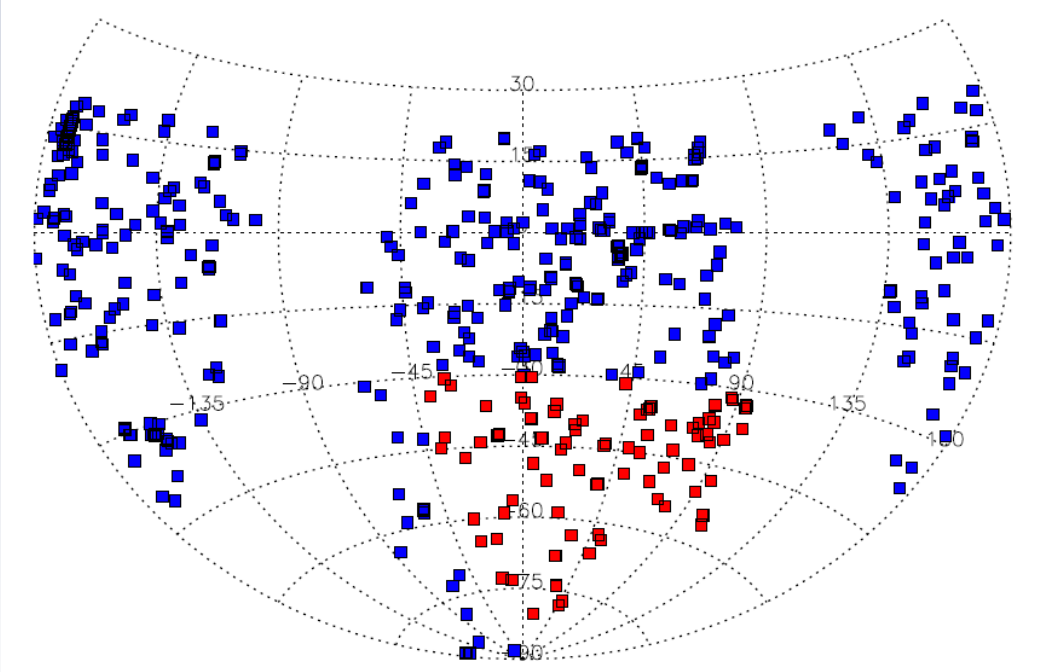
Status 09 Apr 08

- public: **5300**
- imaging mode: **3600**
- low N_H: $|b| \geq 20$deg, no LMC,SMC,M31
- deep exposures ≥10ksec: **2000**
- non survey region (COSMOS etc): **1900 / 300 deg^2**
- VLT accessibility: DEC<+20deg: **1100**
- quality: FoV filling target, flared, etc **(-20%)**

- SPT coverage: **250 / 40 deg^2**

XDCP Survey Fields (Nov 2004)

survey covers ~ ½ of current Southern archive fields



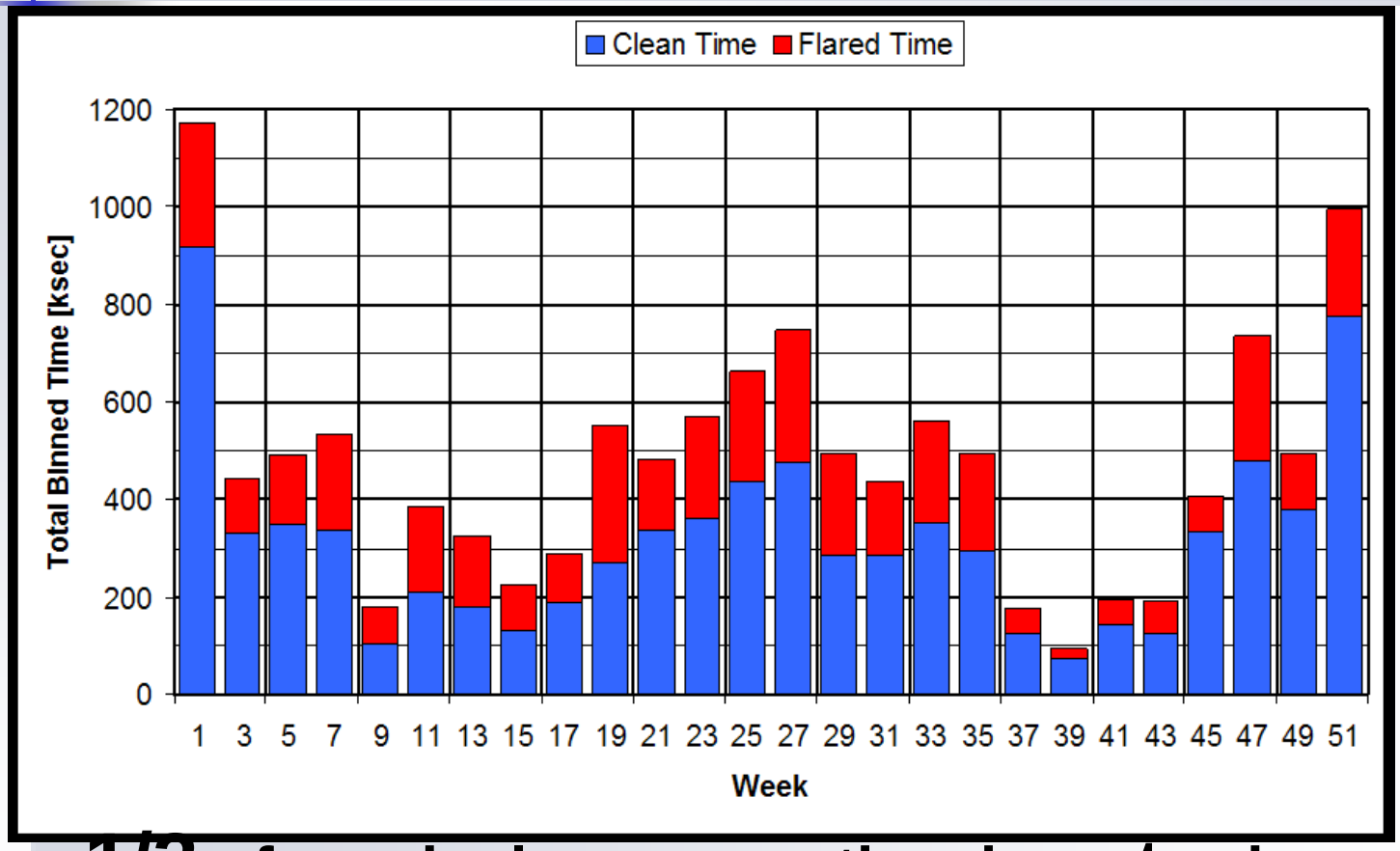
100 fields with SPT coverage

- 470 survey fields analyzed
- 80 deg^2 / 50 deg^2 ($\Theta \leq 12'$)
- 15.2 Msec data
- 8.8 Msec clean time

- XXL-like amount of X-ray data
- depth & area comparable to XXL-like survey

Science Usable Clean Time

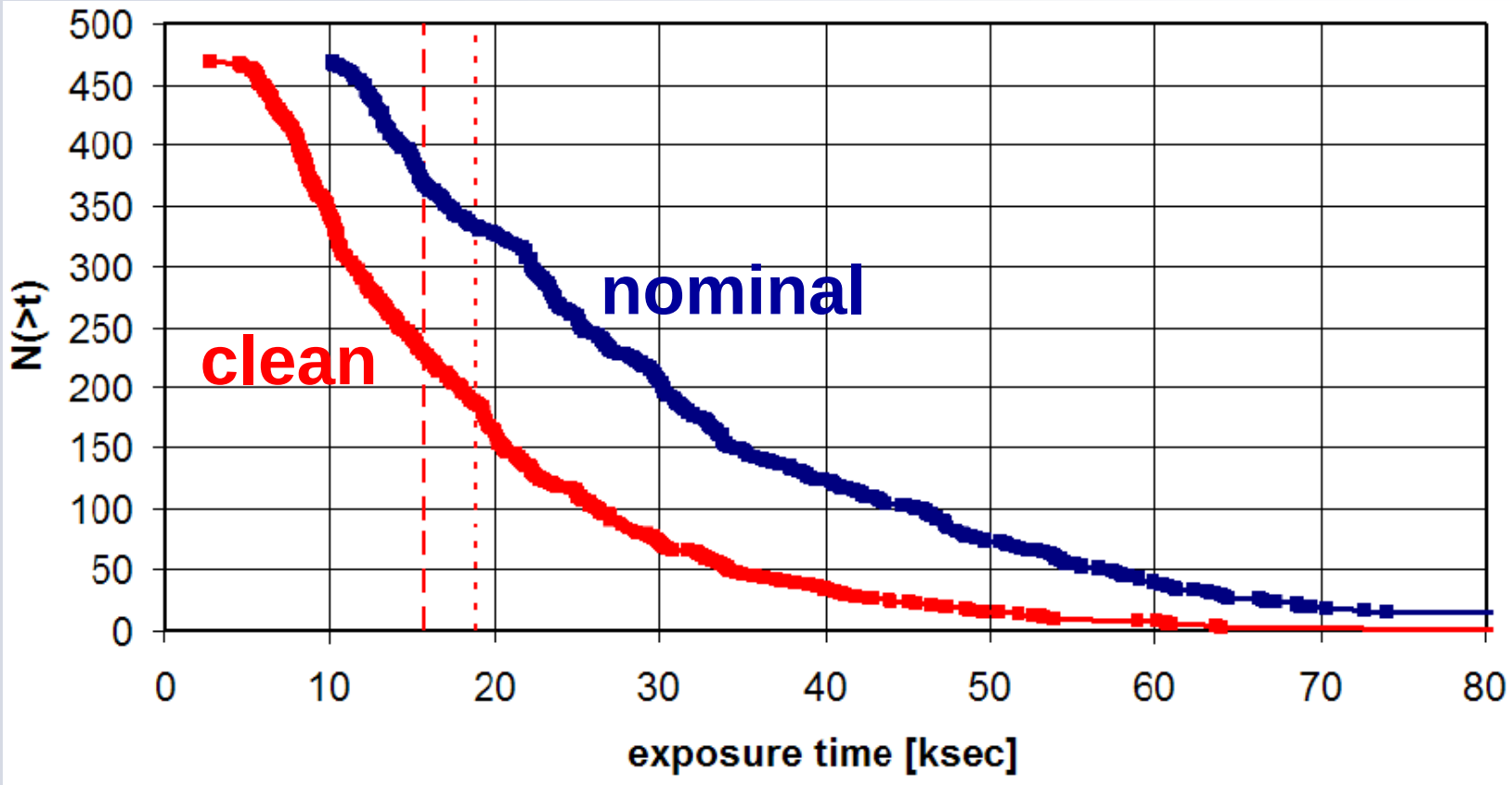
as a function of the season



1/3 of nominal exposure time is not science usable:
flare losses + instrument overheads

XDCP Survey Fields

cumulative exposure time distribution

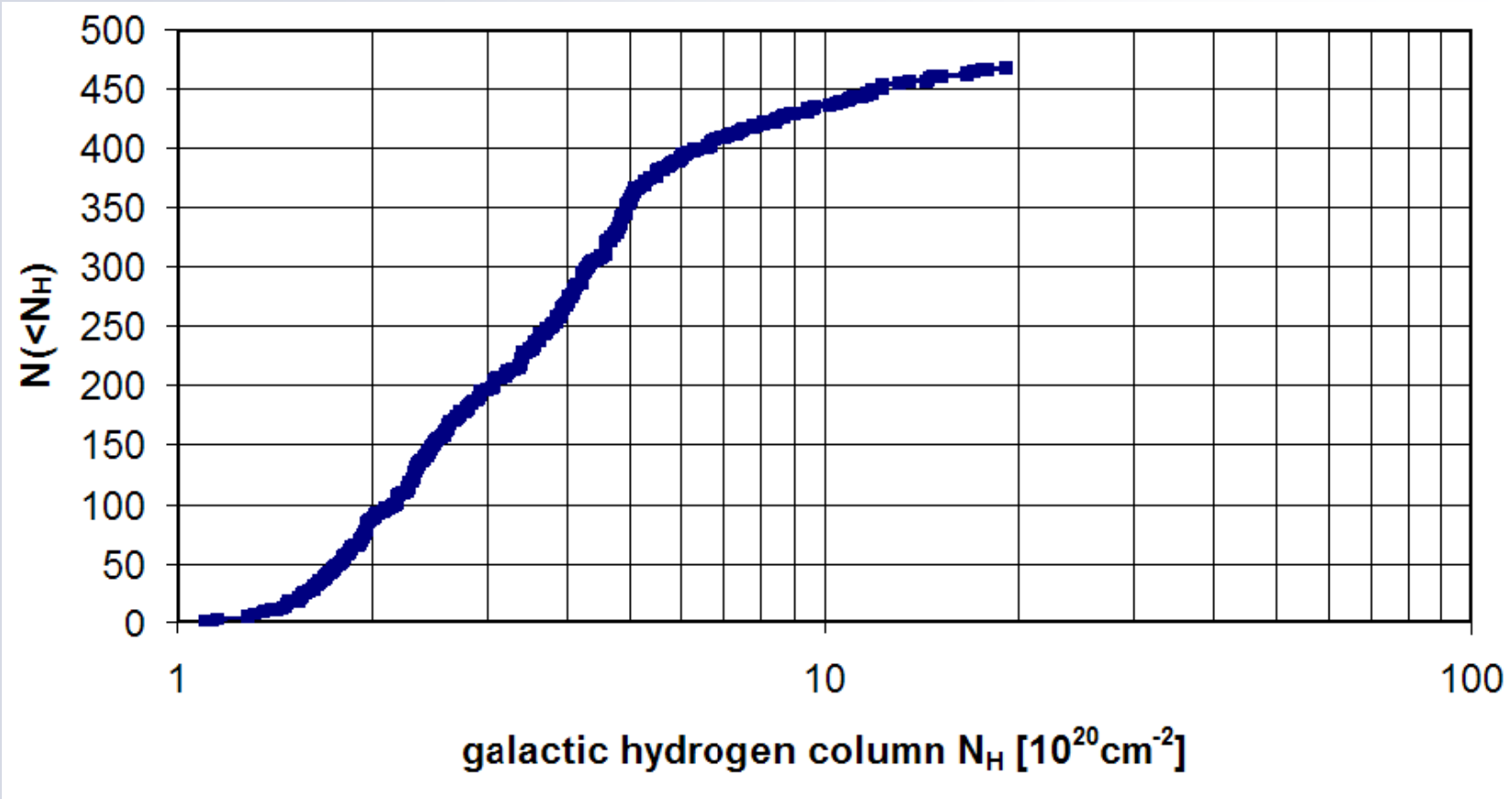


average clean time per field: **18.8ksec**
median clean time per field: **15.7ksec**

total **nominal** time: **15.2 Msec**
total **clean** time: **8.8 Msec**

N_H Distribution of XDCP Fields

median $N_H \sim 3.5 \times 10^{20}$



Plots from PhD thesis (2007) : http://edoc.ub.uni-muenchen.de/7938

i. The XMM-Newton Distant Cluster Project

ii. XMM Archive Potential

iii. Distant Cluster Finding in X-rays

iv. Optical Follow-up

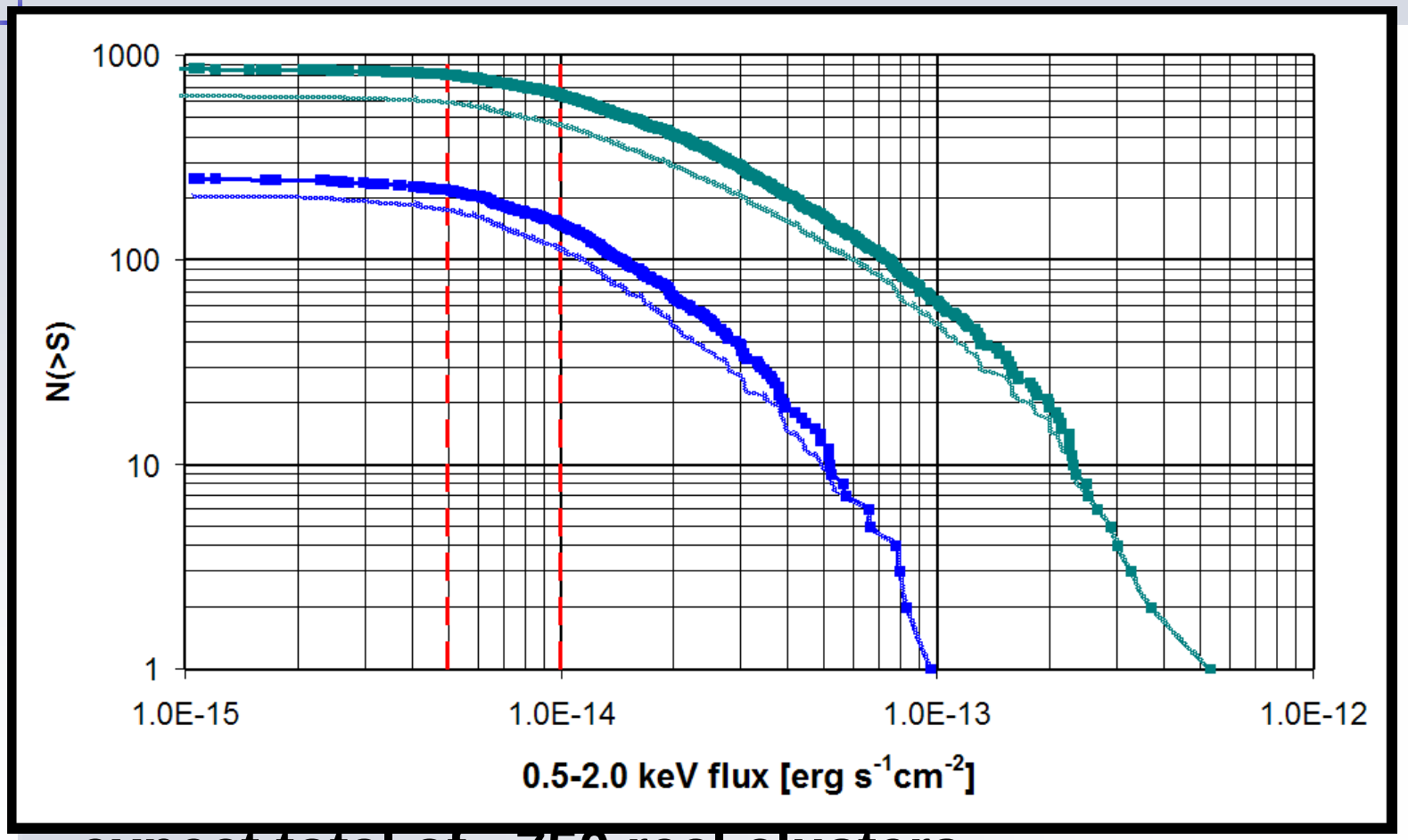
v. Conclusions

XDCP Source Detection

- extended source detection and characterization with **SAS** tasks *eboxdetect+emldetect*
- *ewavelet* used as cross-check
- for distant cluster work sources with extent likelihoods down to 2-3 sigma level are considered
- source lists have to be screened manually at this significance level

~250 distant cluster candidates
+ 700 DSS identified candidates

with about 25% contamination prior to follow-up



expect total of ~750 real clusters

10 deg^{-2} (full FoV) / 12 deg^{-2} (Θ≤12arcmin)

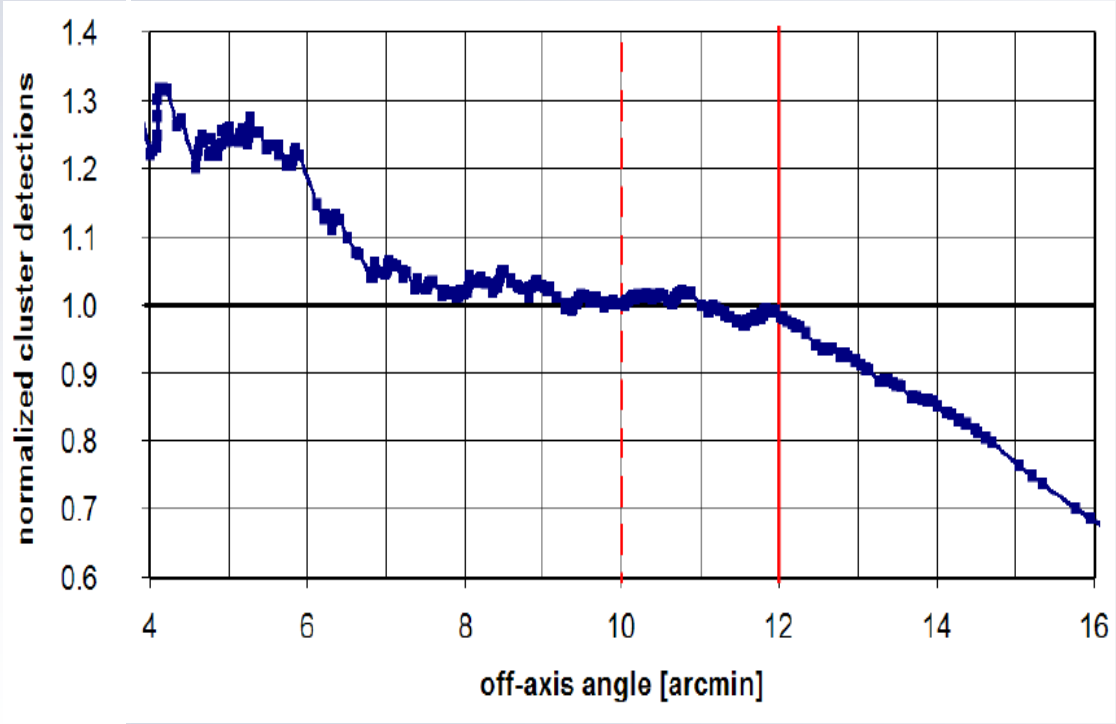
Main Causes for Spurious Extended Sources with XMM

- detections in **wings** of large extended sources
- PSF **calibration** errors at large off-axis angle
- **blends** of 3 or more point sources
- **background** residuals
- chip boundary **artifacts**
- **out-of-time** residuals
- **optical loading** residuals

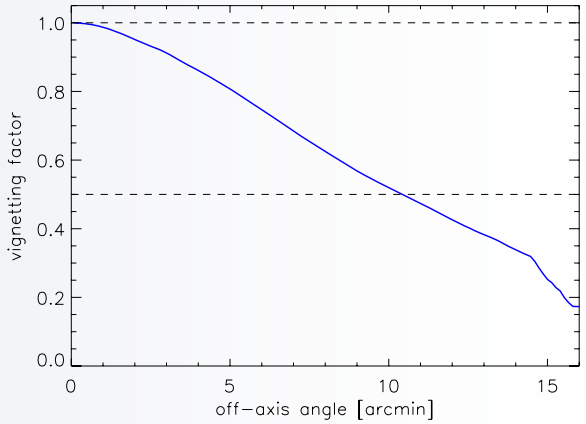
Survey Usable Detector Area

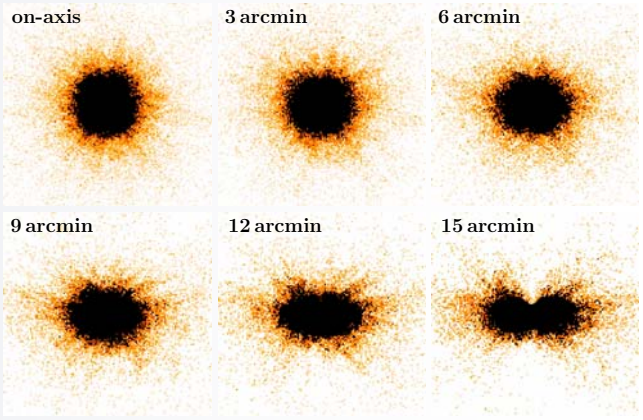
inner 12’ are well behaved (8 fields deg^{-2})

normalized cluster detections per unit area as function of off-axis angle

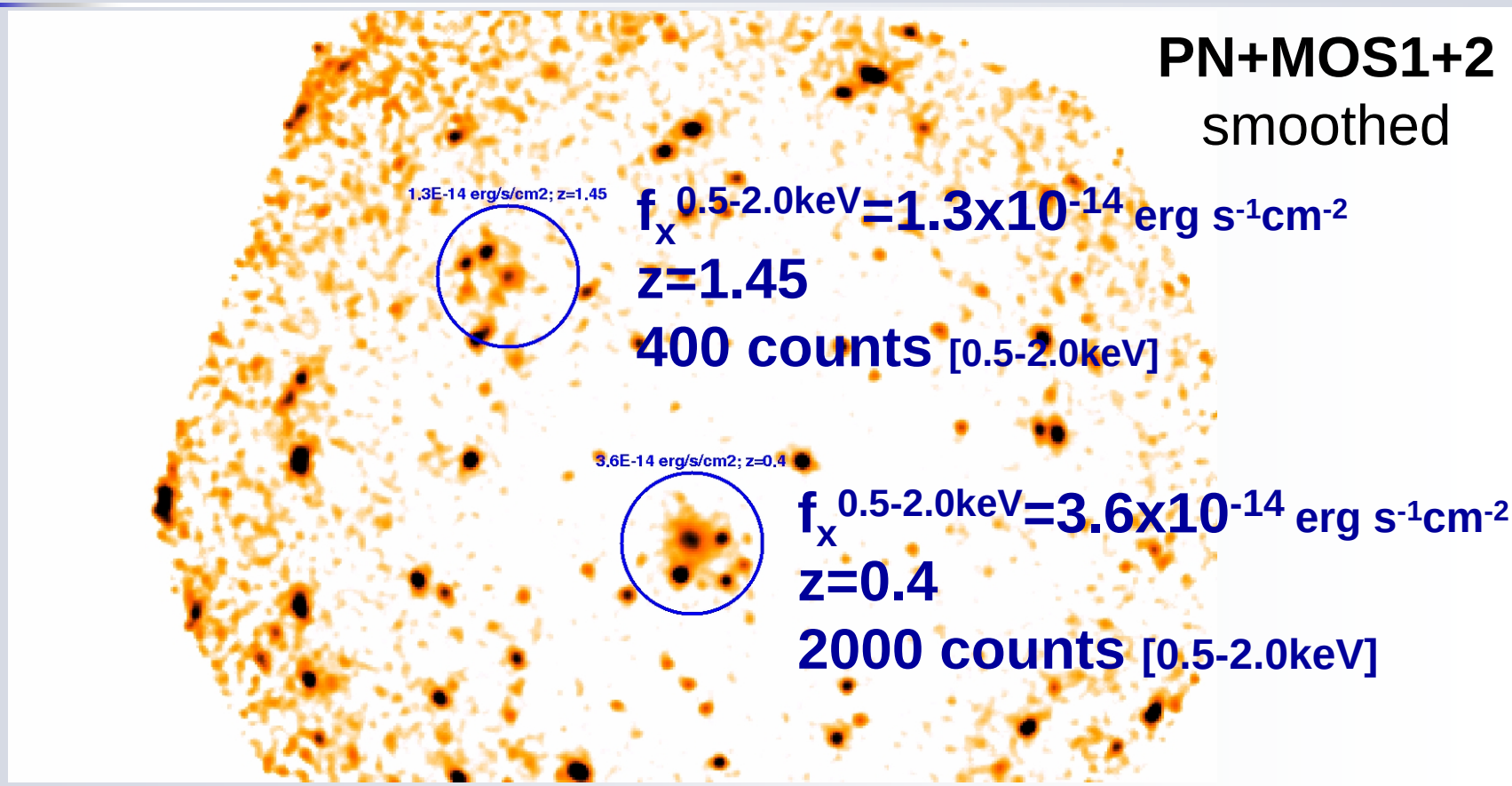


Vignetting & PSF





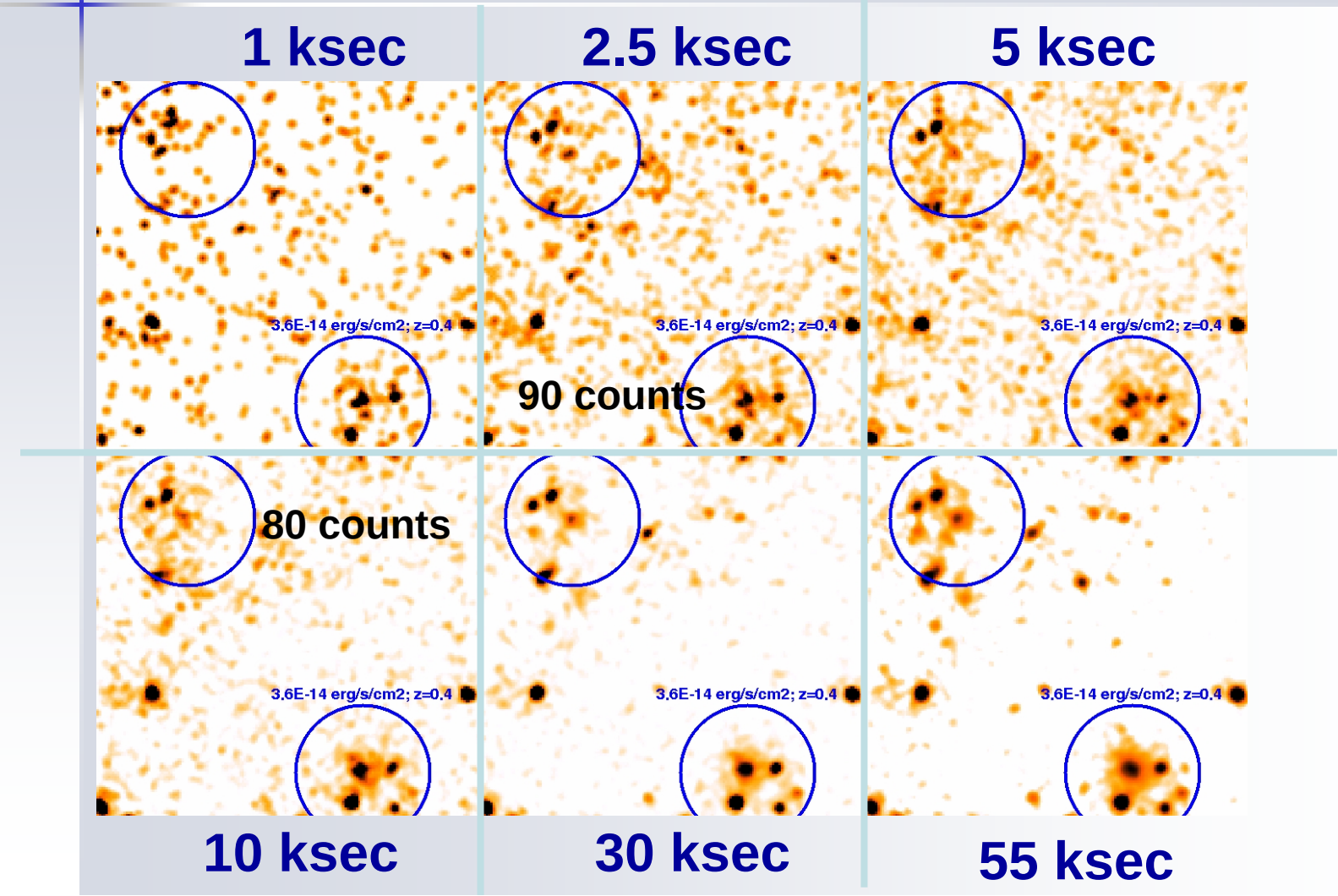
Detectability of Real Clusters



LBQS 2212-1759 field; 55ksec clean exposure time

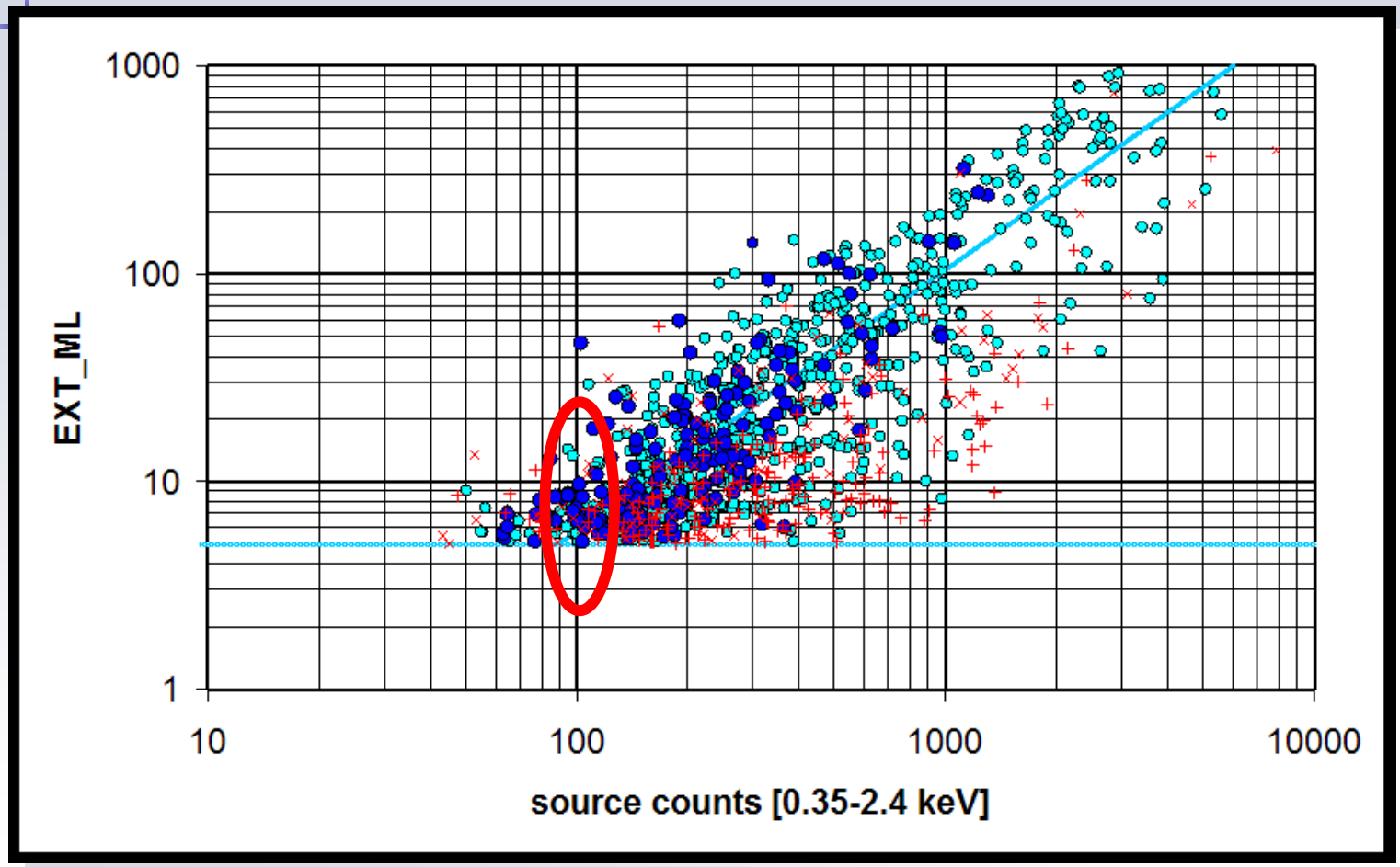
100 counts required

for a ‘controlled’ extent determination



Extended Source Characteristics

extent likelihood vs source counts

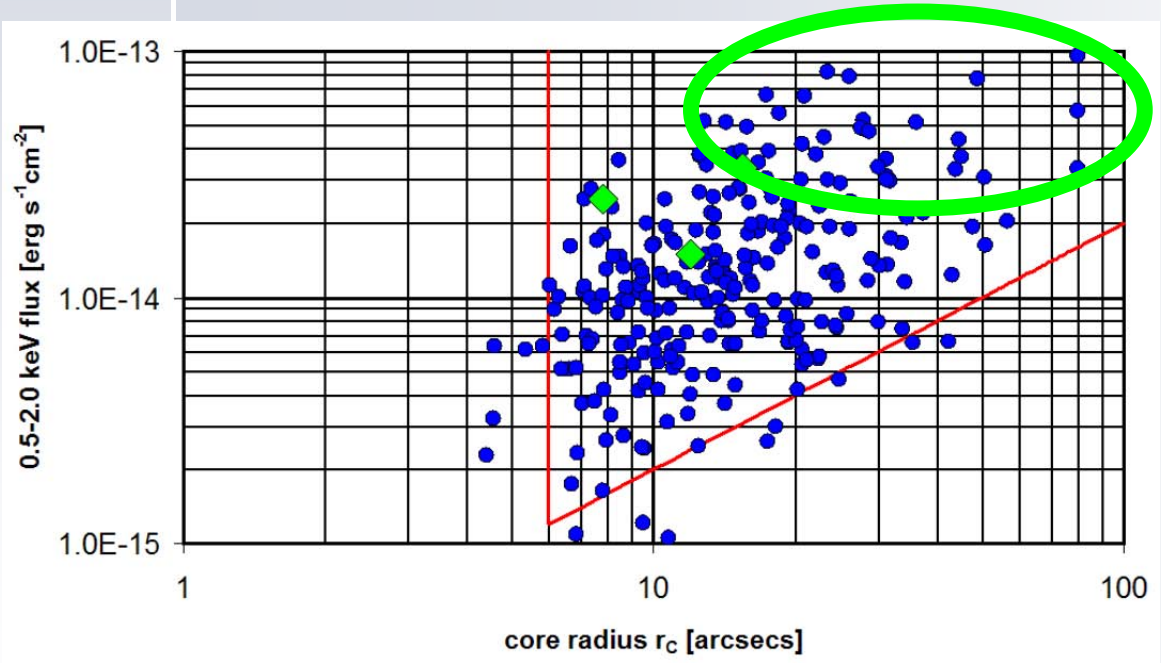


100 counts allow on average a ~4σ extent determination with a fair part of parameter space accessible

Accessible Parameter Space

confined by resolution and background limit

distant cluster candidates in flux-extent plane



Detection Efficiency

- cluster flux
- cluster extent
- cluster morphology
- AGN contamination
- background

background limit: $f_{\mathrm{lim}} \propto r_c$

Required exposure time

for a $f_X = 1 \times 10^{-14}$ erg s^{-1} cm^{-2} [0.5-2keV] survey

- 'controlled' X-ray selection with ~100 counts [0.35-2.4keV]
- need 12 ksec effective clean time on-axis
- average vignetting factor at $\Theta \leq 12'$ ~ 0.65 (x1.5)
- average flare & overhead losses ~ 1/3 (x1.5)

an average survey sensitivity of $f_X = 1 \times 10^{-14}$ erg s^{-1} cm^{-2} requires roughly 25ksec nominal exposure time (200 ksec per square degree)

Contiguous Area vs Serendipitous Cluster Surveys

Serendipitous

- X-ray data available
- usually deeper & wider
- only bottlenecks: men power & spectros. time

- no clustering info
- inhomogeneous data
- more contamination
- selection function more challenging to obtain

XXL

- more homogeneous data
- well selected field(s)
- more controlled selection
- clustering info

- X-ray data requirements
- mulitband+spect. follow-up
- depth?
- requires well-coordinated enormous efforts

i. The XMM-Newton Distant Cluster Project

ii. XMM Archive Potential

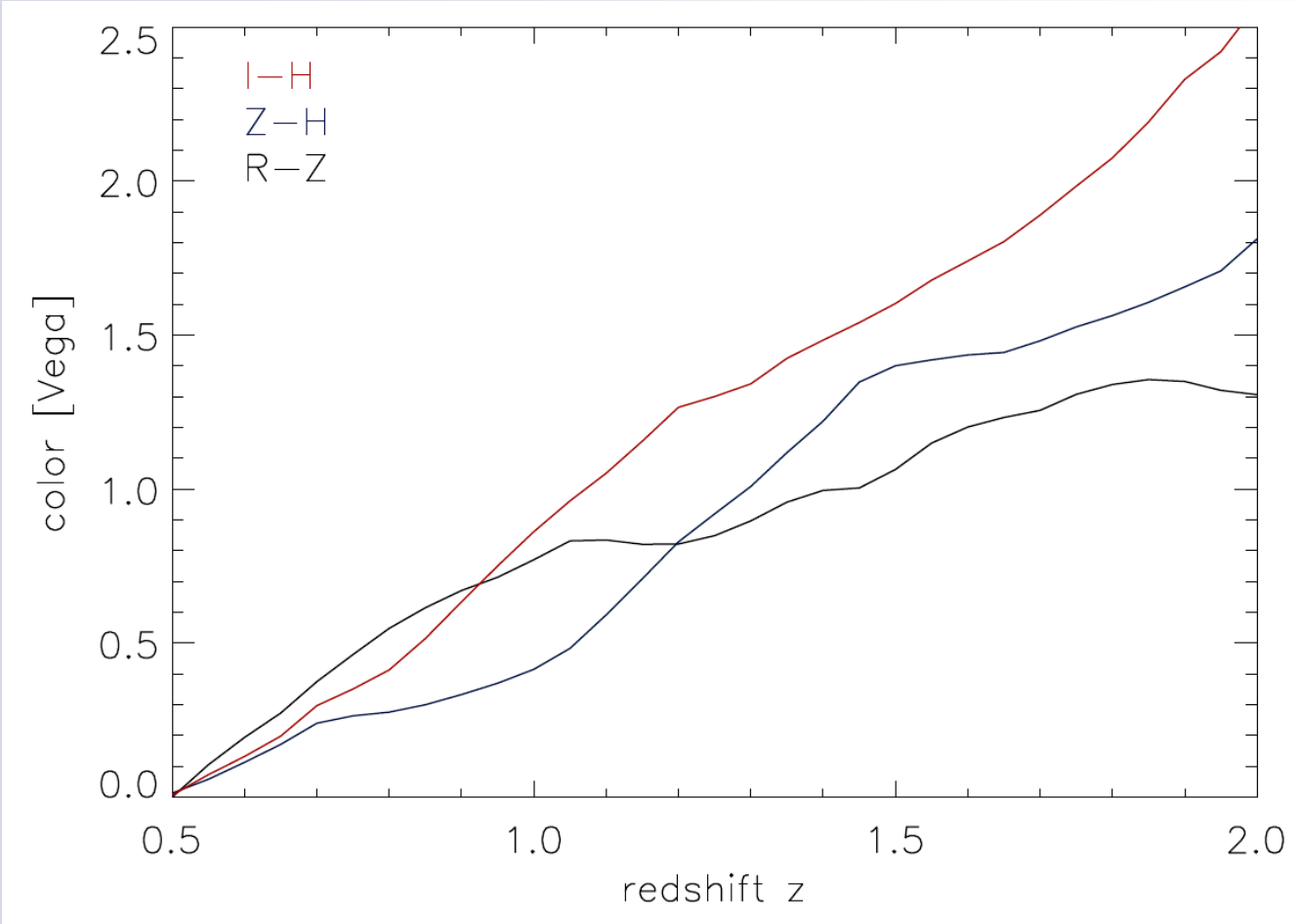
iii. Distant Cluster Finding in X-rays

iv. Optical Follow-up

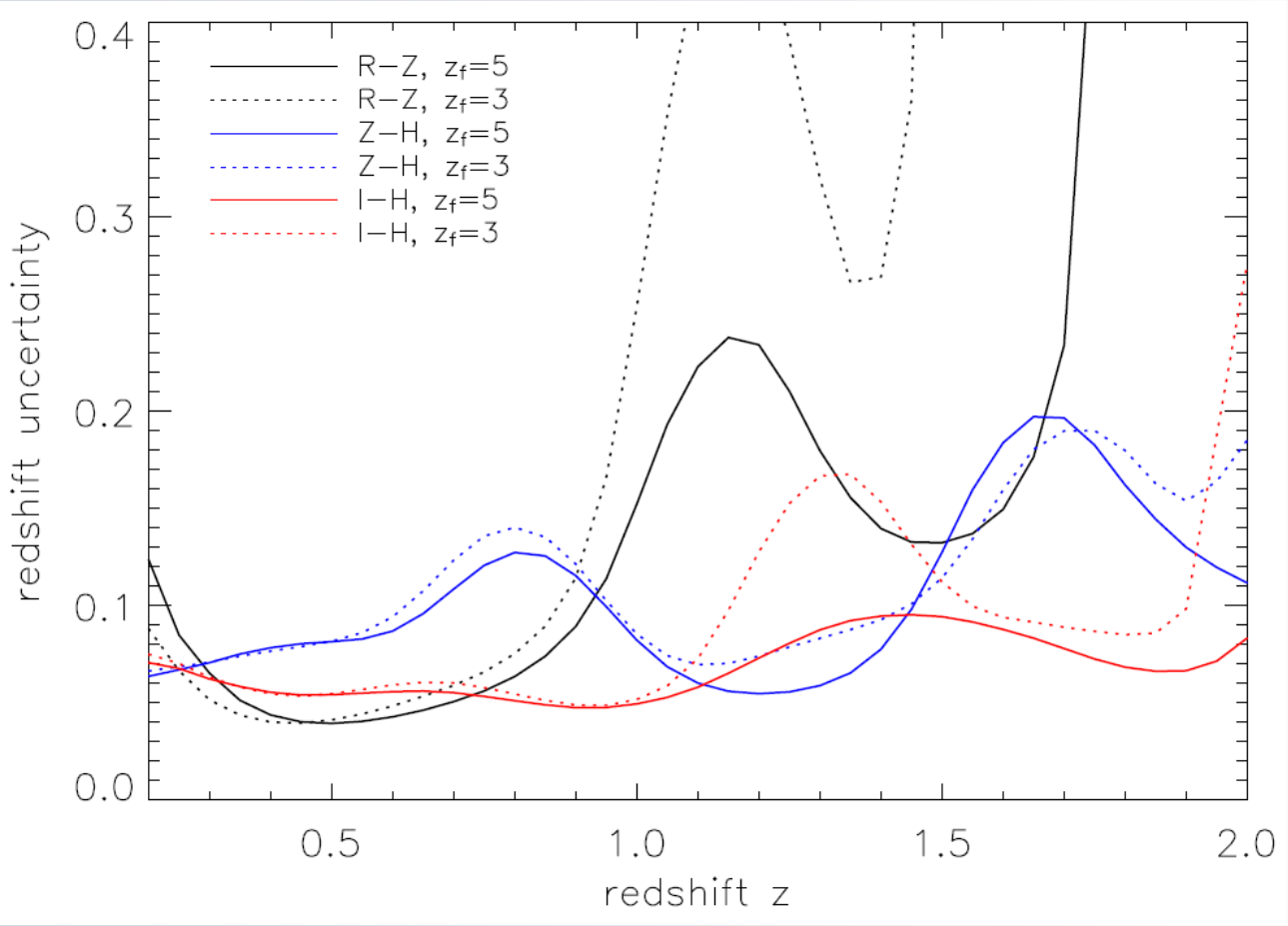
v. Conclusions

z-H red-sequence imaging

NIR techniques provide good redshift estimates out to z~1.5



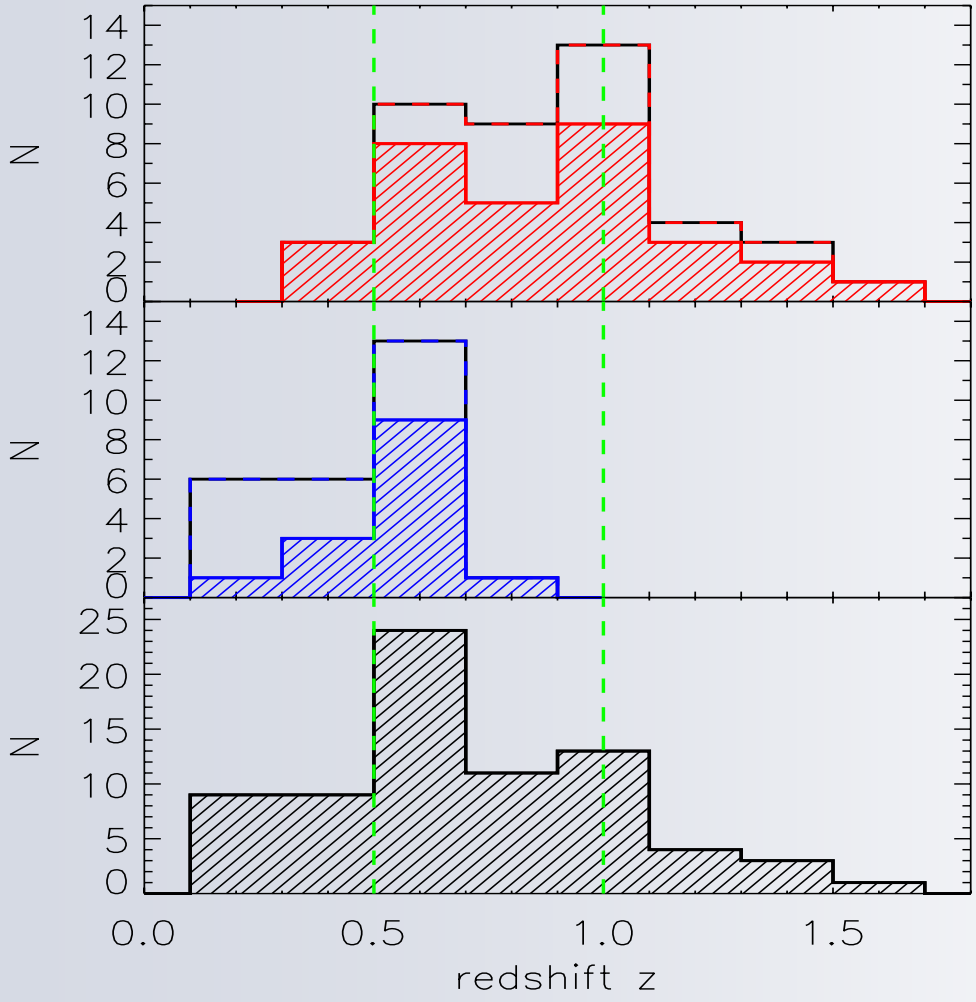
Expected Photometric Redshift errors



assume σ_{color}~(1+z) *0.05 mag

Calar Alto Imaging Results

red-sequence redshift estimates



distant cluster candidates

~1/4 of XDCP sample

~20 at $z_{est} \geq 0.9$

DSS candidates (in FoV)

full cluster sample (including targets)

Ongoing Science Projects

- in-depth study of XMMU J2235-2557 at z=1.393 (Rosati et al., in prep)
- supercluster studies at z~1 (Fassbender et al., 2008)
- X-ray cluster studies in very deep fields (Lamer et al., in prep)
- spectroscopic reduction and analysis of a dozen high-z candidates ongoing
  - verification of NIR red-sequence redshift estimates
  - environmental effect studies
  - galaxy evolution studies

i. The XMM-Newton Distant Cluster Project

ii. XMM Archive Potential

iii. Distant Cluster Finding in X-rays

iv. Optical Follow-up

v. Conclusions

Conclusions

- XDCP is a good pathfinder for XXL in terms of X-ray data amount and depth
- XMM archive has high potential for cluster studies but also limitations
- a well controlled cluster survey at 10^{-14} erg s^{-1} cm^{-2} level requires about 200ksec per square degree
- NIR data crucial for high-z end

BACKUP

Confirmed z>1 X-ray Clusters

Status 2006

XMMXCS J2215.9-1738 **z=1.45**
XCS (Stanford et al., 2006)

XMMU J2235.3-2557 **z=1.393**
XDCP (Mullis et al., 2005)

CIG J0848+4453 **z=1.273**
RDCS (IR-selected)

RX J0848.6+4453 **z=1.261**
RDCS

RX J1252.9+2927 **z=1.237**
RDCS

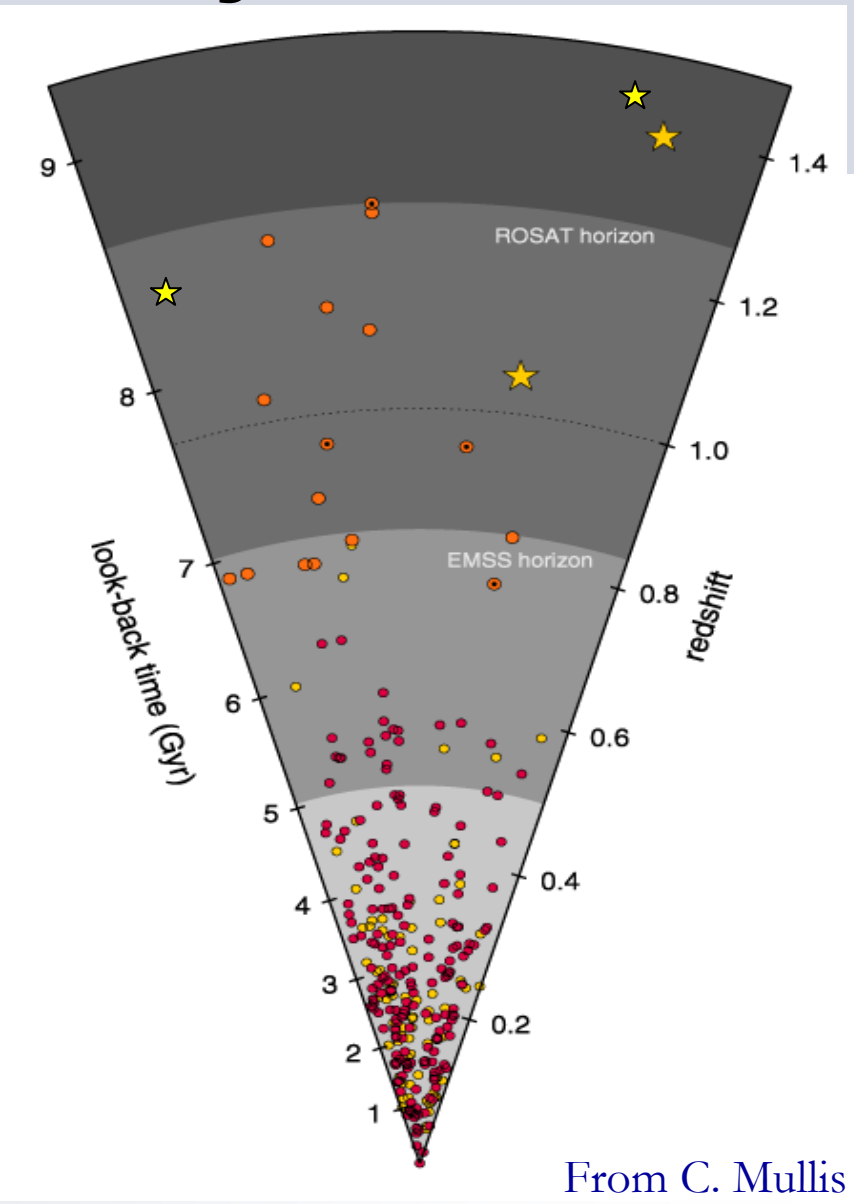
XLSS J022303.3-043622 **z=1.22**
XMM-LSS (Bremer et al., 2006)

RX J1053.7+5735 **z=1.14**
Lockman Hole

RX J0910+5422 **z=1.106**
RDCS

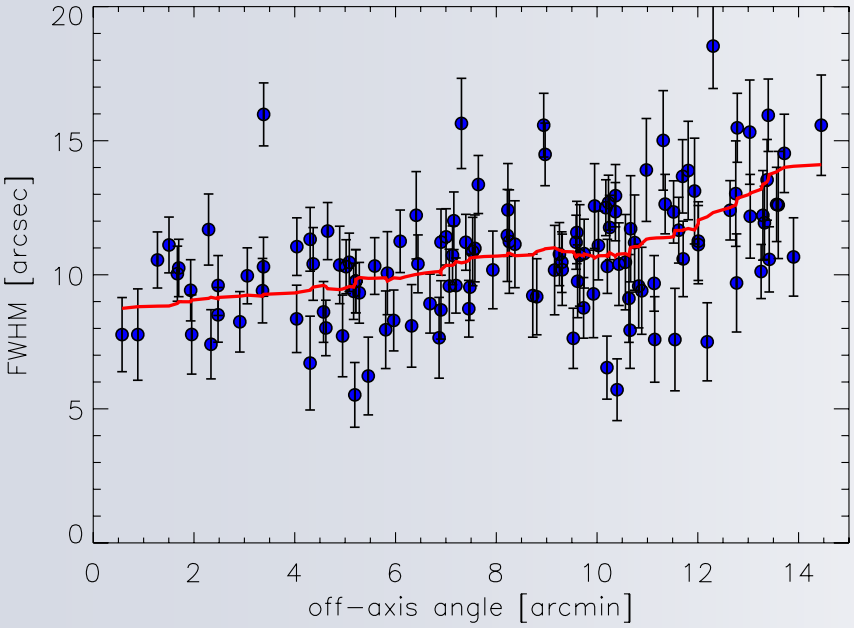
XLSS 022403.9-041328 **z=1.05**
XMM-LSS (Andreon et al., 2005)

Cl J1415.1+3612 **z=1.03**
WARPS

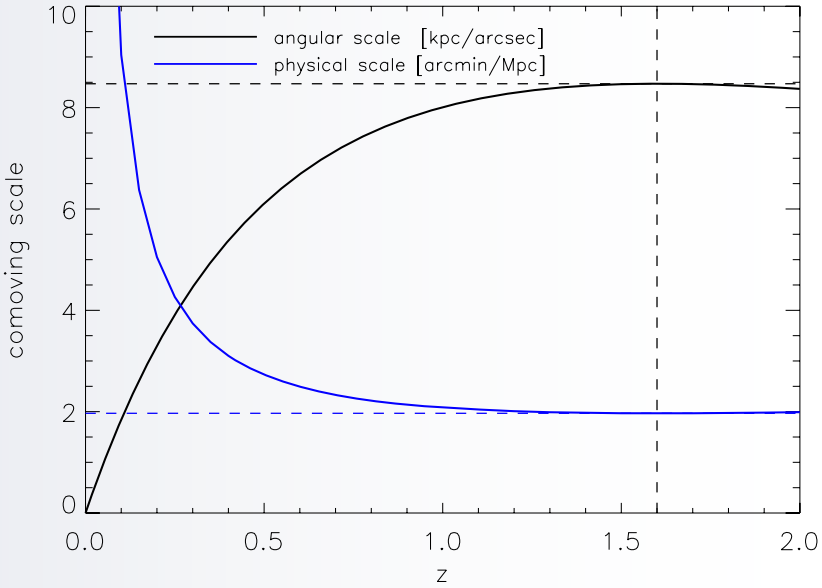


From C. Mullis

II. Resolution



6-15 arcsec FWHM

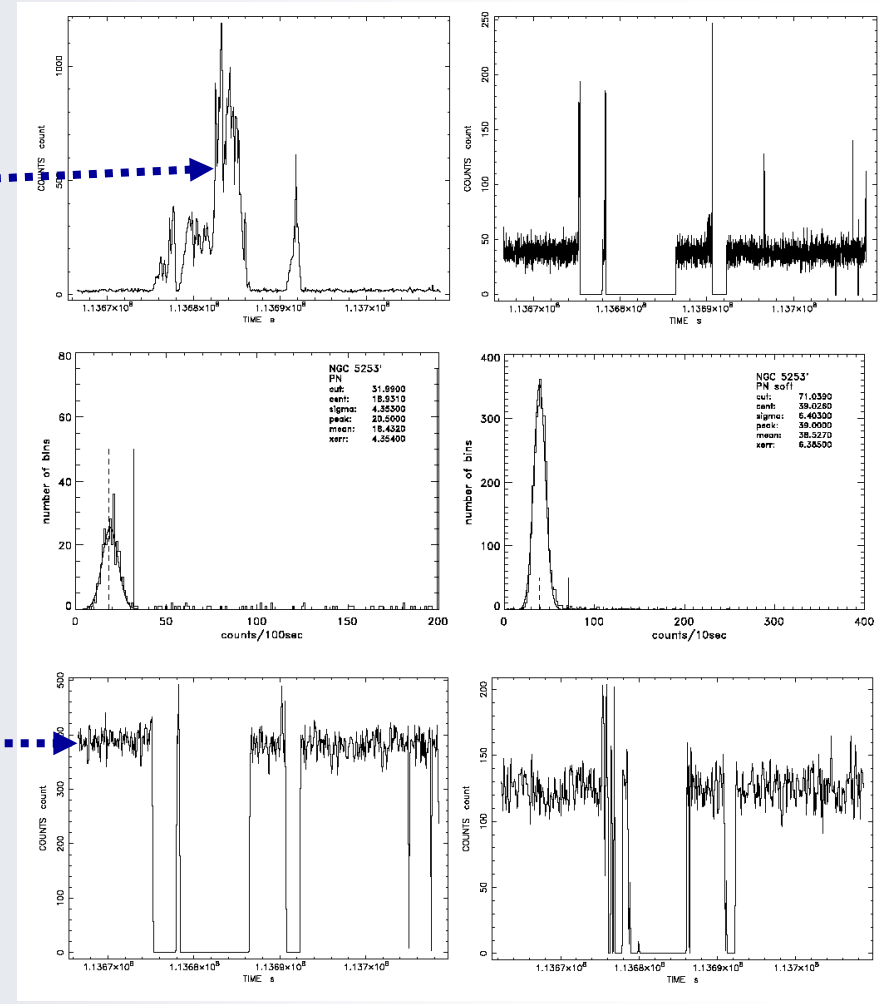


50-130 kpc at z>0.8

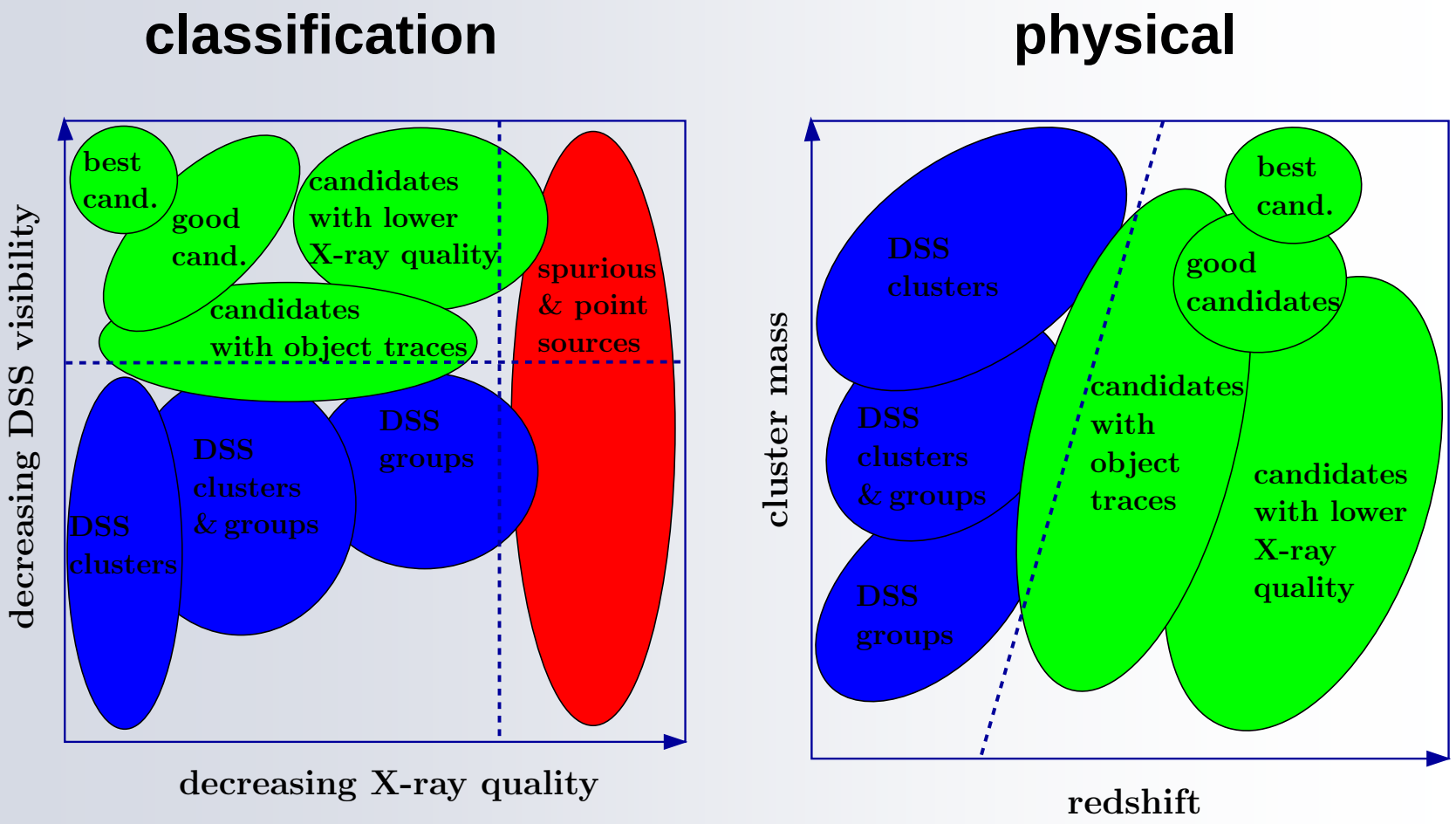
Background level
Limitation III

soft proton flare

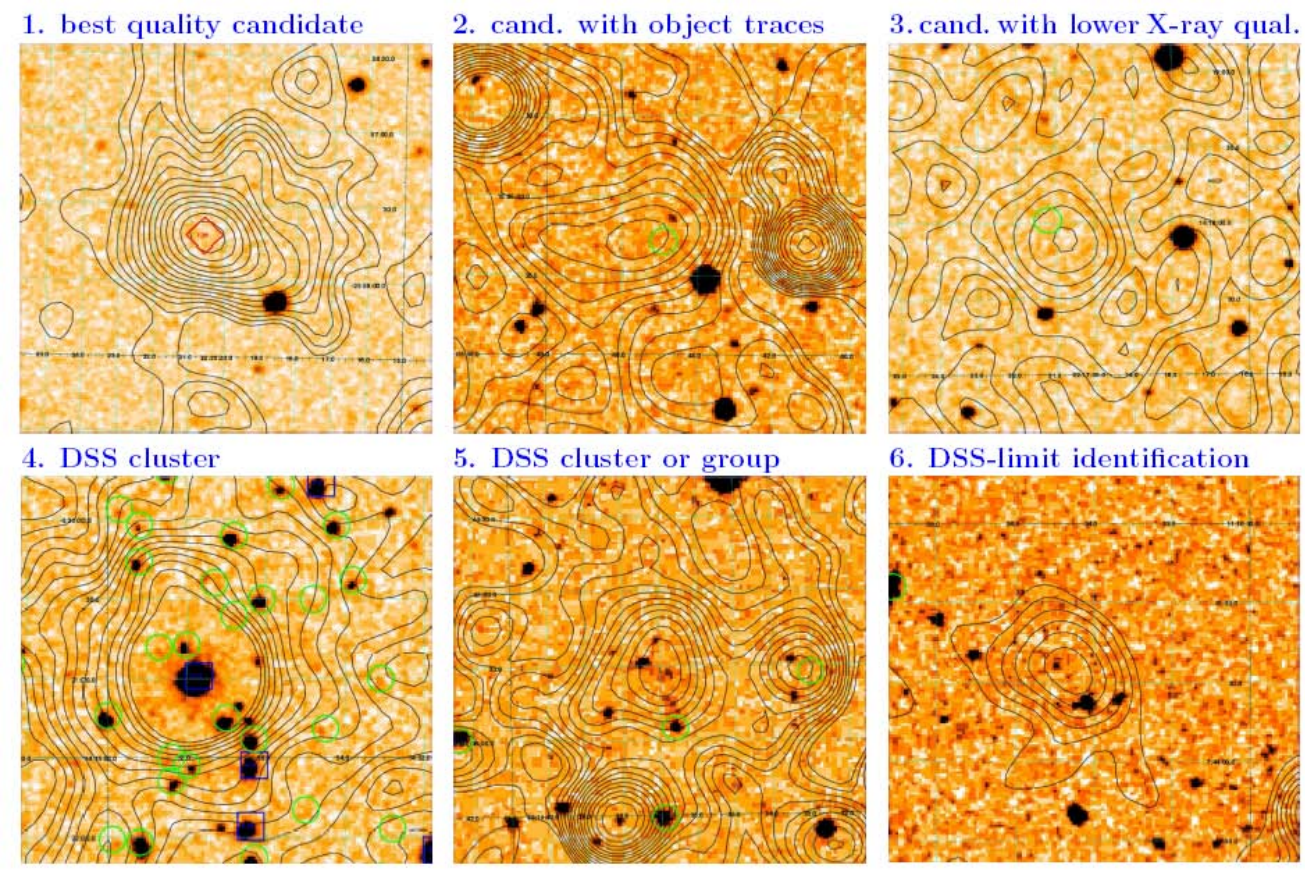
quiescent background



Cluster Candidate Classes

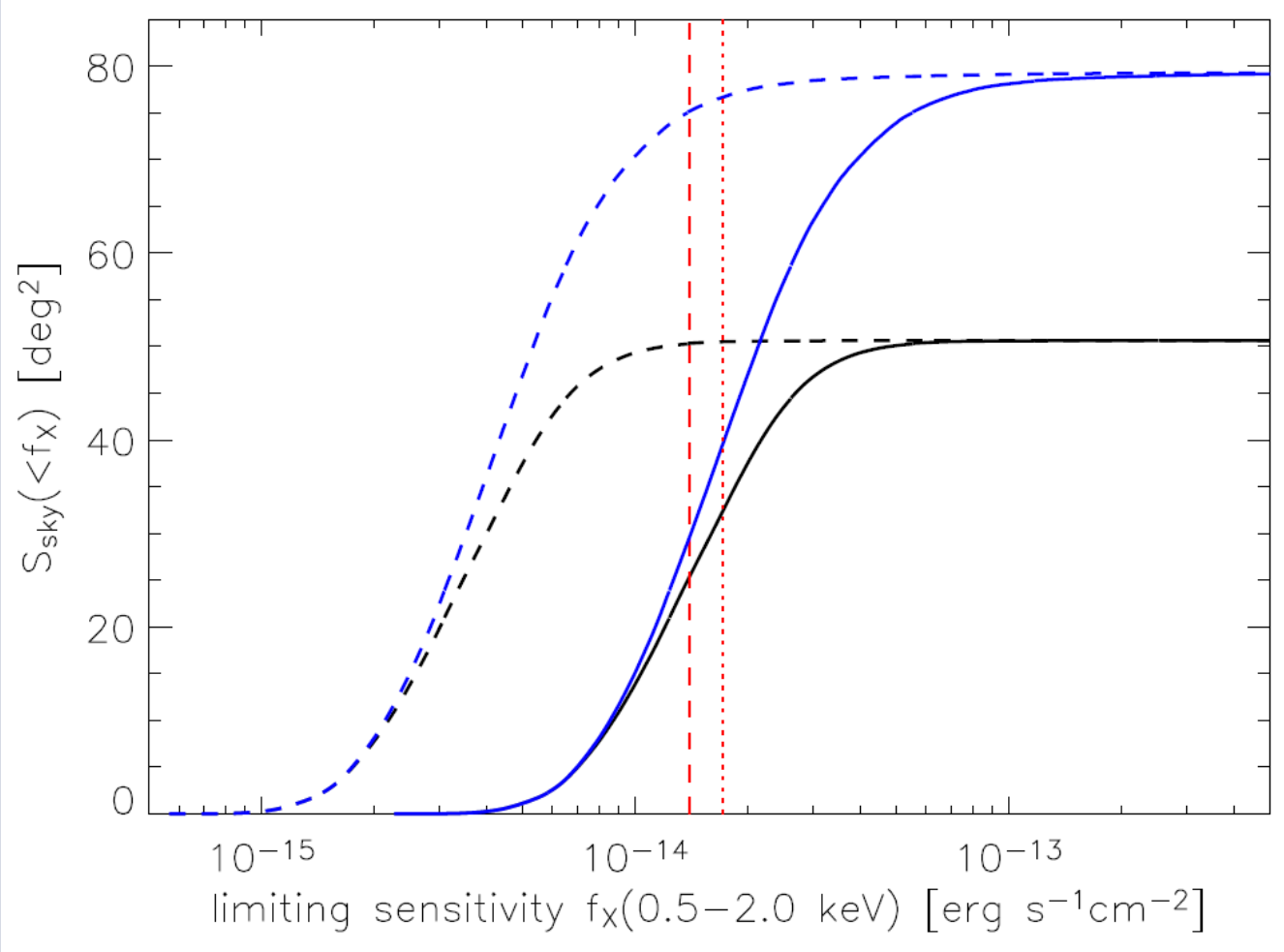


Cluster Candidate Prototypes



distant cluster candidates

DSS flagged clusters candidates


80
60
40
20
0
$S_{sky}(<f_X)$ [deg^2]
10^{-15}
10^{-14}
10^{-13}
limiting sensitivity f_X(0.5−2.0 keV) [erg s^{-1}cm^{-2}]

Selection Function

Roadmap for XDCP

- simulate each XMM survey field ~10^2 times
- use of hydrodynamical clusters simulations as mock input clusters (rather than beta models)
- obtain cluster detection efficiency as function of luminosity, redshift, core radius, morph-ology?, ...

- ...work in progress