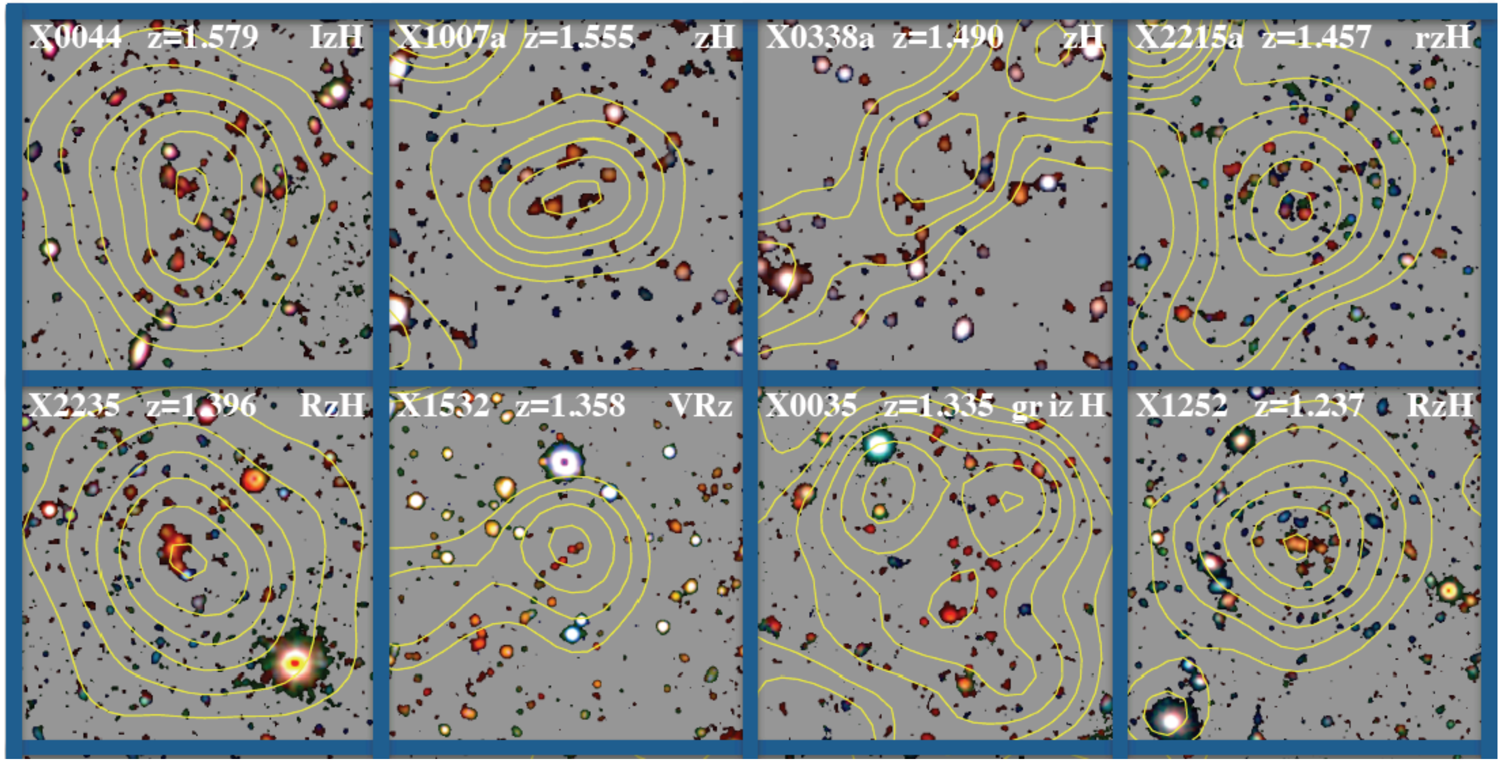
Distant X-ray clusters and their applications with XMM-Newton and eROSITA



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eROSITA Conference, Garmisch, 18. Oct 2011

Agenda

I. Distant X-ray Galaxy Clusters: Science & Status

II. The XDCP Cluster Sample up to z~1.6

III. Prospects and Challenges for eROSITA Cluster Studies at z>1

I. Distant X-ray Galaxy Clusters: Science & Status

Tracing the High-z Evolution of X-ray Galaxy Clusters Observationally

Applications in Cosmology	Applications in Astrophysics

DM structure formation

cluster number density evolution

geometric gas mass fraction test

absolute distances (X-ray+SZE)

large-scale structure/cosmic web

formation of the ICM

thermodynamic evolution of ICM

metal enrichment of ICM

high-z merging of clusters/halos

AGN-ICM interactions at high-z

galaxy-ICM interactions

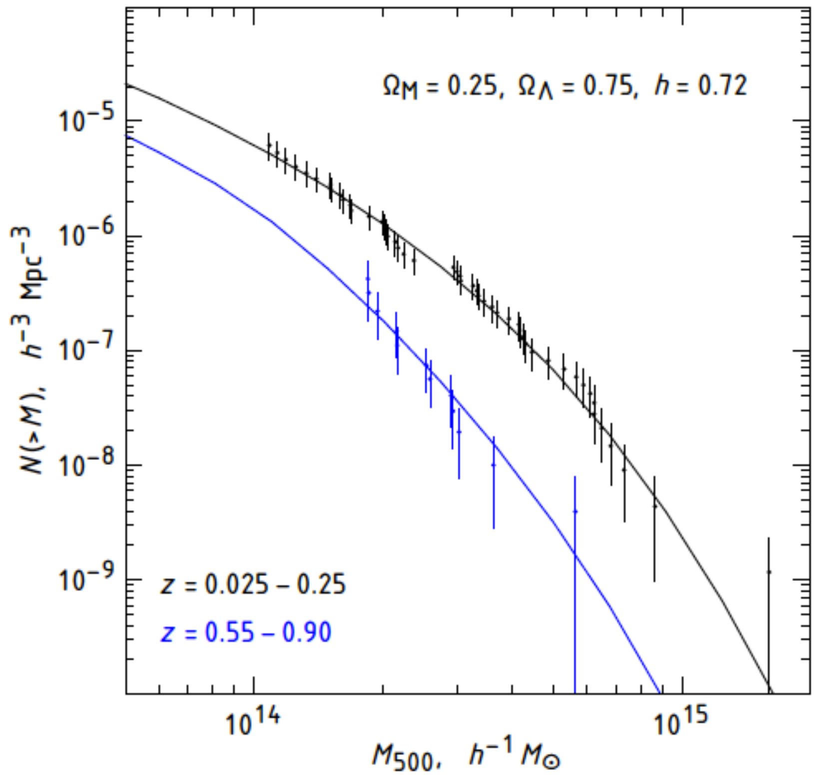
formation of red-sequence galaxies

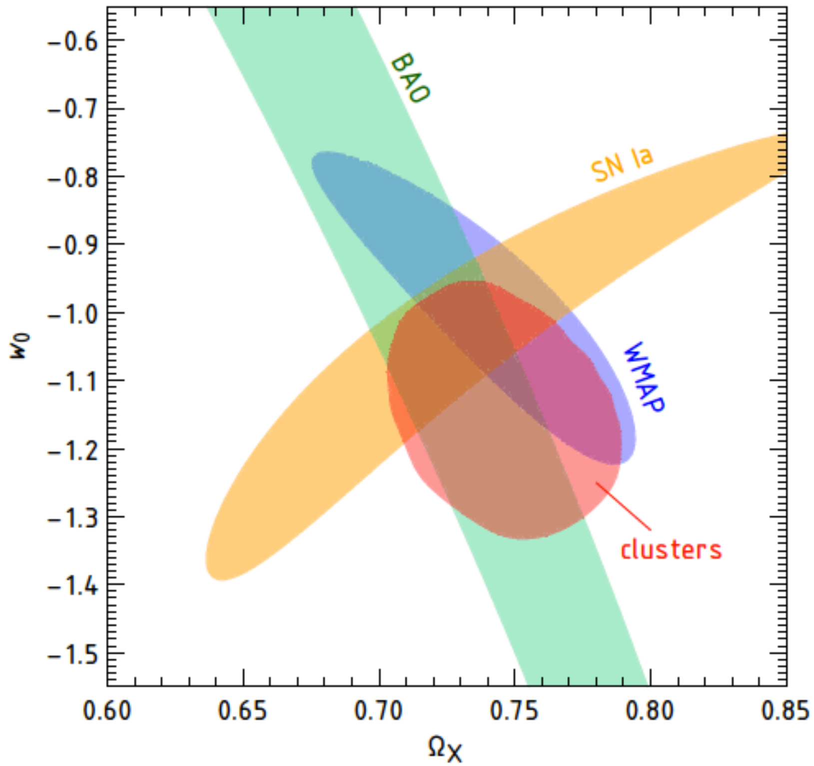
galaxy transformation processes

BCG formation and evolution

Distant X-ray Clusters as Dark Energy Probes

- Dark Energy Constraints based in the evolution of the galaxy cluster mass function are among the best of all individual DE probes, with a high potential for future studies
- current constraints are derived from the comparison of 49 local clusters with 37 intermediate redshift clusters (z>0.35, 17 at z≥0.5, 2>0.8) with <z>=0.55

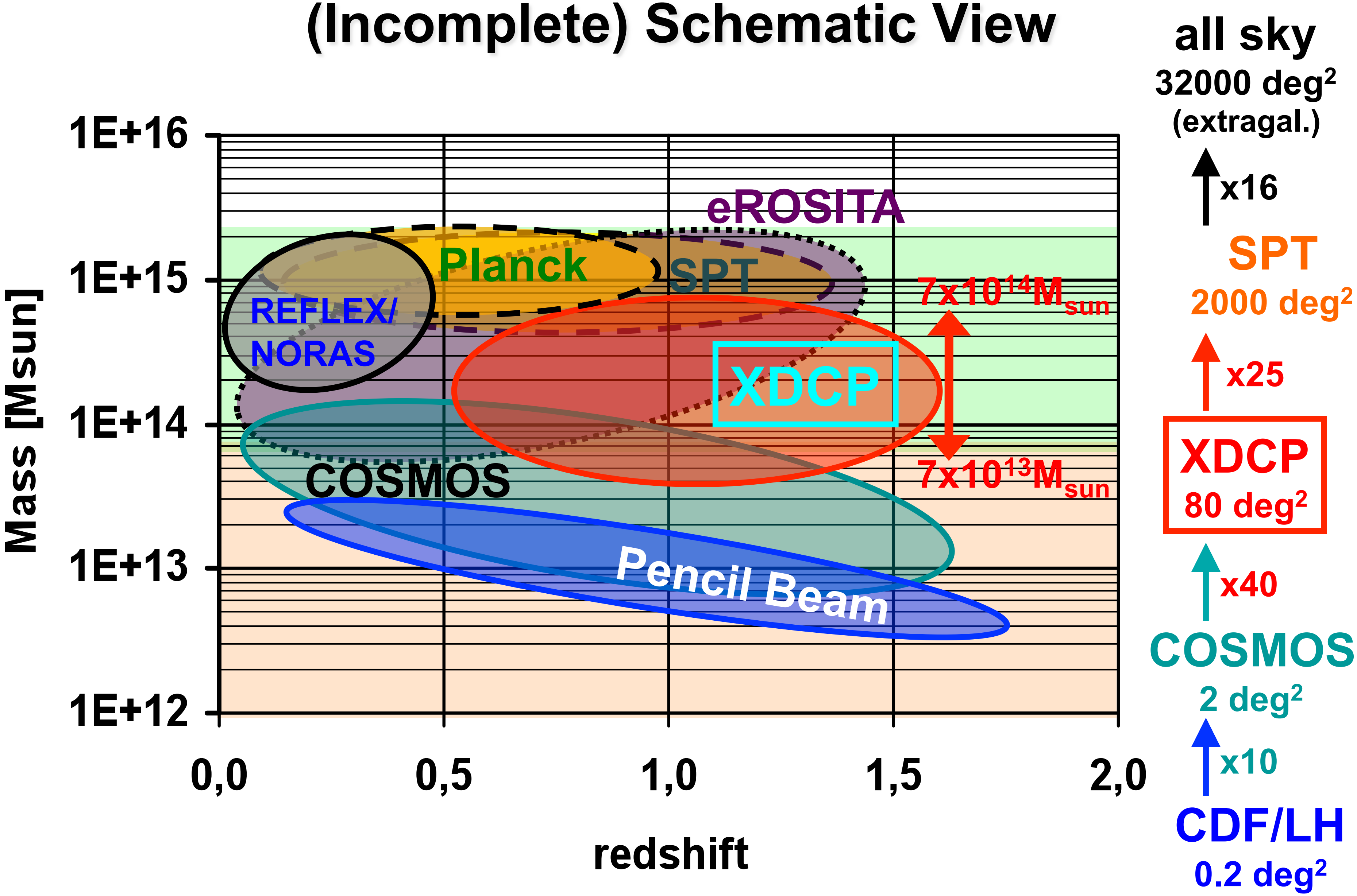




Vikhlinin et al. 2009

Galaxy Cluster Surveys based on ICM Signature

(Incomplete) Schematic View



The top 10 most distant clusters known

spectroscopically confirmed + X-ray signature

z	Name	Sel.	$L_{X,bol}$ [10^{44} erg/s]	M200 [$10^{14} M_{sun}$]	References
2.07	CL J1449+0856	MIR	0.9	0.7	Gobat+11
1.75	XMMU J1053+5723	Xray	0.5	0.6	Henry+10
1.62	XCL J0218-0510	MIR	0.4	0.7	Tanaka+10, Pierre+11 Papovich+10
1.58	**XMMU J0044-2033**	**Xray**	**6.1**	**3.0**	Santos+11
1.56	**XMMU J1007.4+1237**	**Xray**	**2.1**	**1.7**	Fassbender+11
1.49	**XMMU J0338+0021**	**Xray**	**1.1**	**1.2**	Nastasi+11
1.49	ISCS J1432.4+3250	MIR	3.5	2.5	Brodwin+10
1.46	**XCS J2215.9-1738**	**Xray**	**2.2**	**2.0**	Hilton+10, Stanford+06, Bielby+10
1.41	ISCS J1438.1+3414	MIR	2.2	2.2	Brodwin+10, Stanford+05
1.39	**XMMU J2235.3-2557**	**Xray**	**10.0**	**6.6**	Rosati+09, Jee+09, Mullis+05

II. The XDCP Cluster Sample up to z~1.6

The XMM-Newton Distant Cluster Project Team

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Jan Kohnert (AIP)
Gabriel Pratt (Saclay)
Joe Mohr (USM Munich)
Hernan Quintana (U Catolica)
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Alessio Romeo (U Andres Bello)

A XMM-Newton Distant Cluster Project (XDCP) Primer

Aim: find & study distant X-ray clusters at z>0.8

Science Goals:

– multi-wavelength studies of distant clusters
– galaxy evolution in the densest environments
– high-z scaling relations
– cluster number density evolution

XDCP Assets:

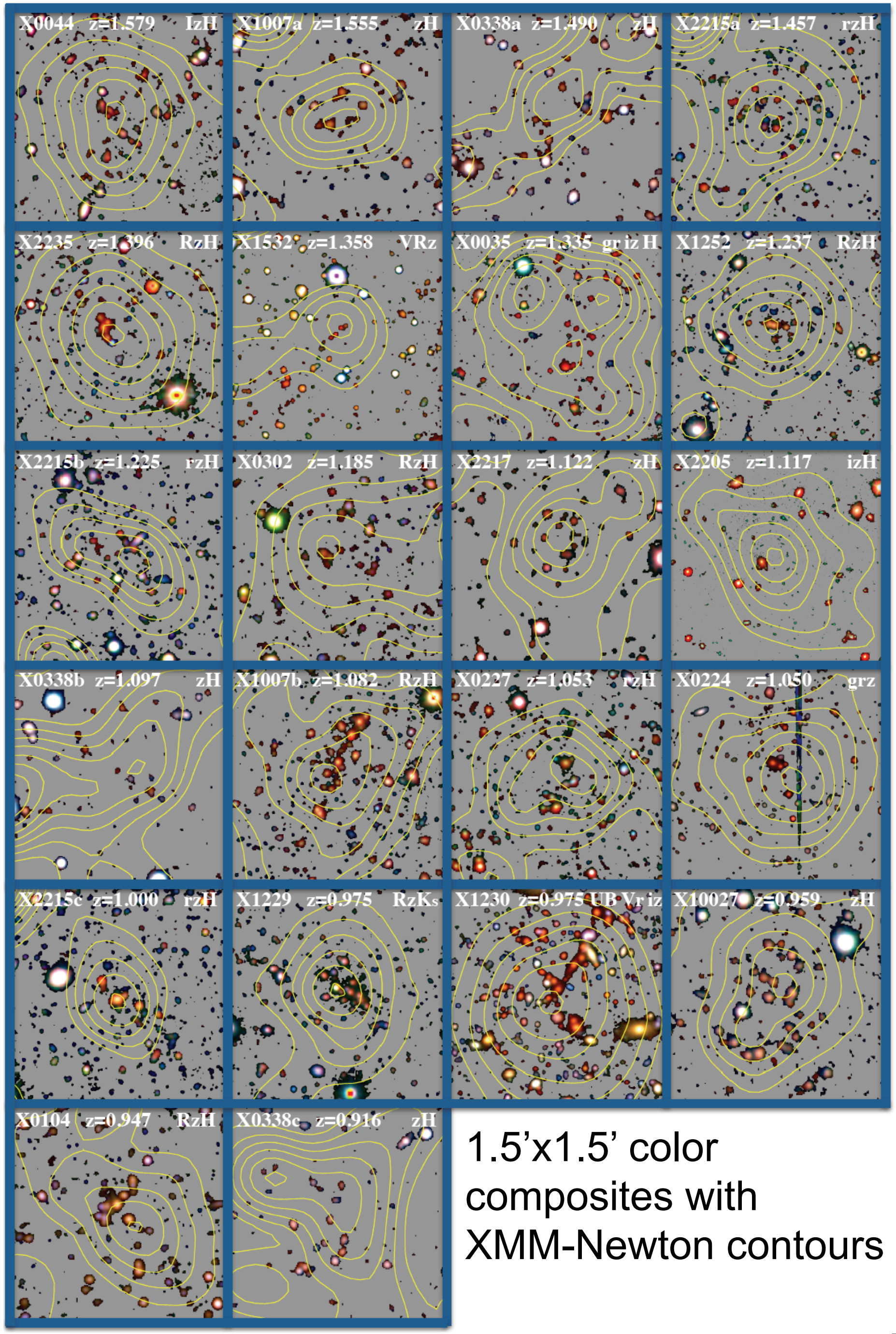
– >200 X-ray selected candidates at z>0.5 from 76deg^2 (49deg^2 core area)
– follow-up imaging data for >90% of distant candidates and for >400 X-ray clusters over all redshifts
– spectroscopic follow-up of high-z candidates >50% complete
– largest sample of distant X-ray clusters to date

Fassbender 2008, arXiv:0806.0861
http://www.xray.mpe.mpg.de/theorie/cluster/XDCP/xdcp_index.html

The published XDCP Sample of 22 X-ray Clusters at 0.9<z<1.6

17 clusters at z≥1.0

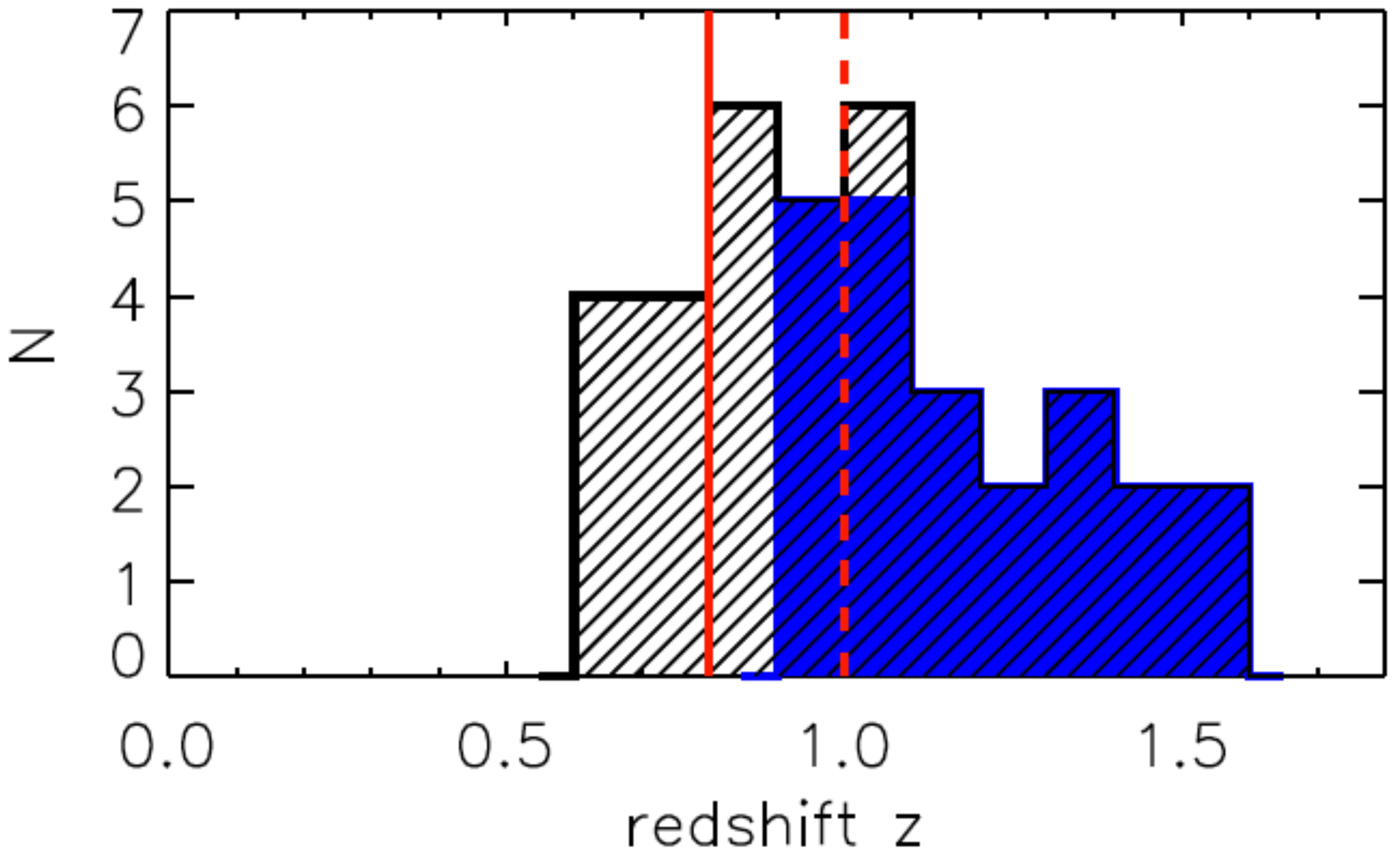
7 clusters at z>1.3



1.5'x1.5' color composites with XMM-Newton contours

Fassbender et al. 2011, on the arXiv soon

Redshift Distribution of the XDCP Cluster Sample

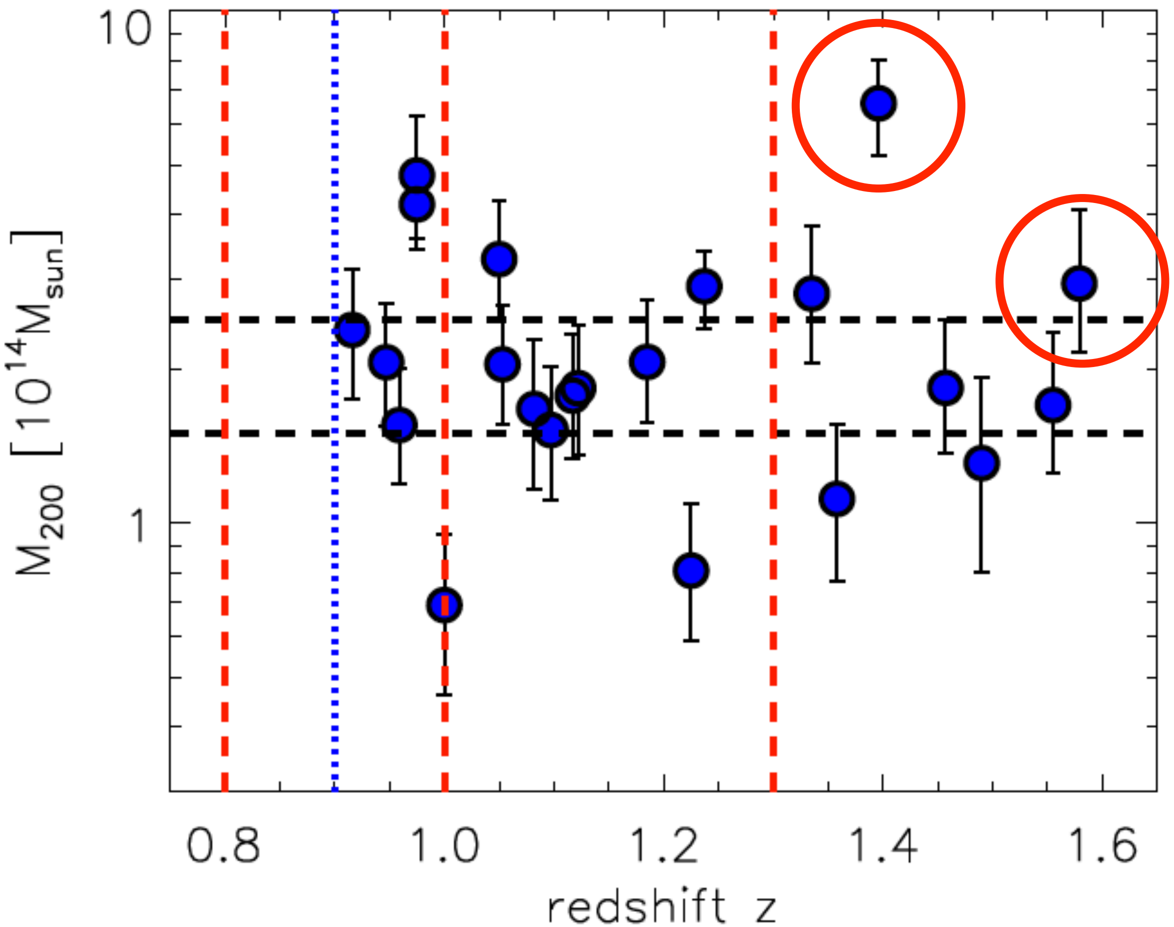


almost homogeneous redshift coverage all the way to z~1.6

full XDCP sample: 33 confirmed systems at z>0.8

Fassbender et al. 2011, on the arXiv soon

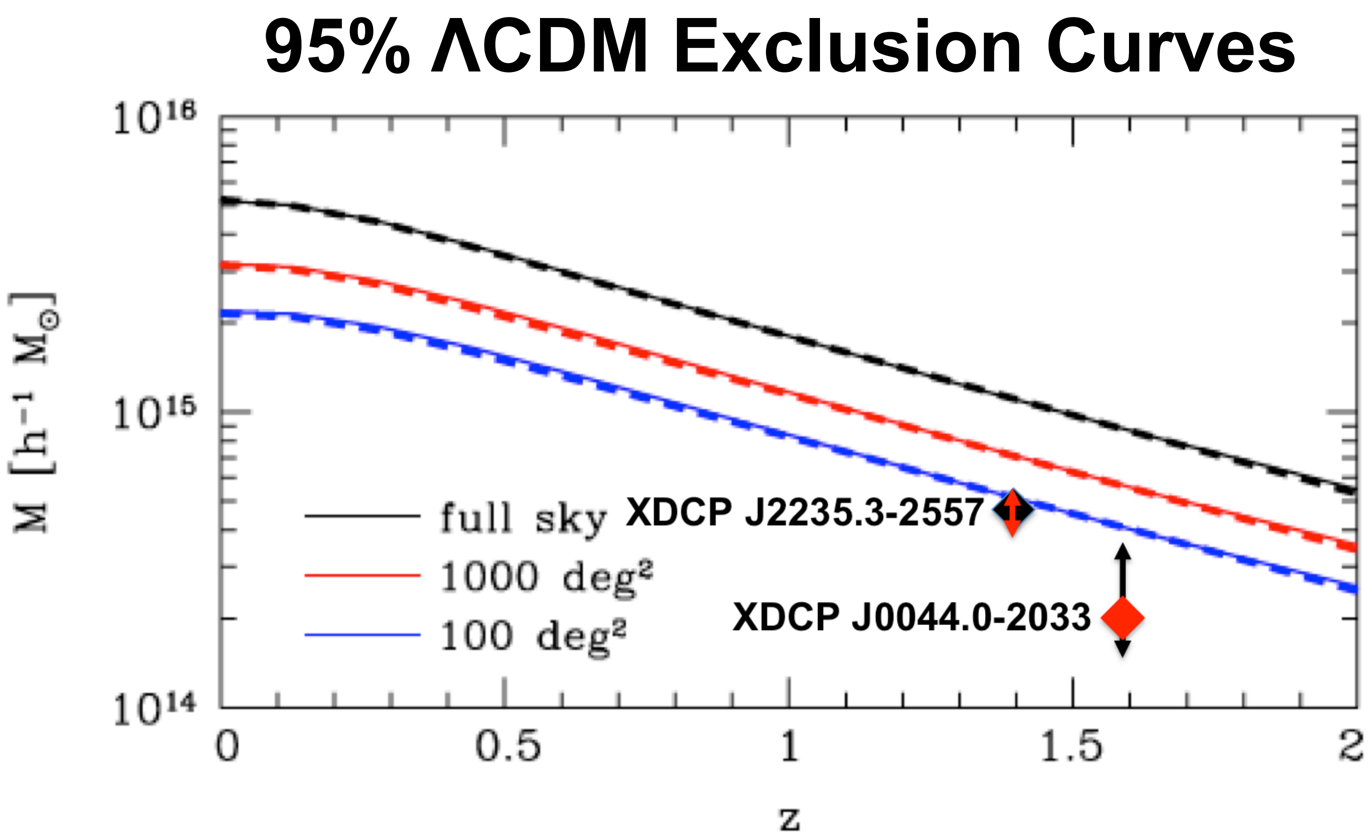
Mass vs Redshift Distribution of XDCP Clusters

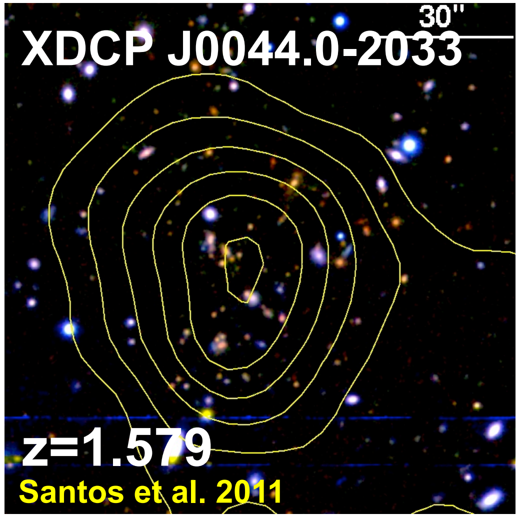


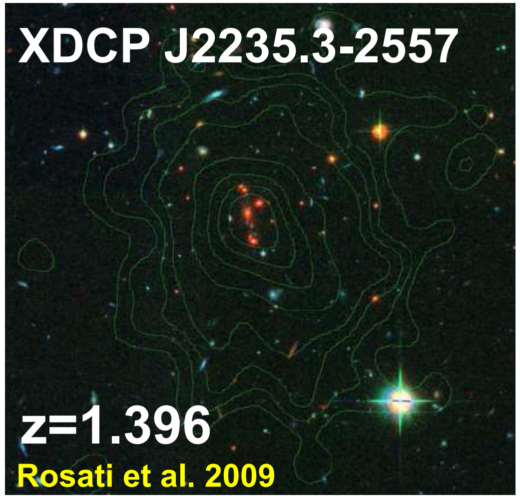
median cluster mass of sample $2{\times}10^{14}\ M_{sun}$

Fassbender et al. 2011, on the arXiv soon

The two least likely XDCP Clusters







exclusion curves from Mortonson et al. 2011

XMMU J1230.3+1339 at z=0.975

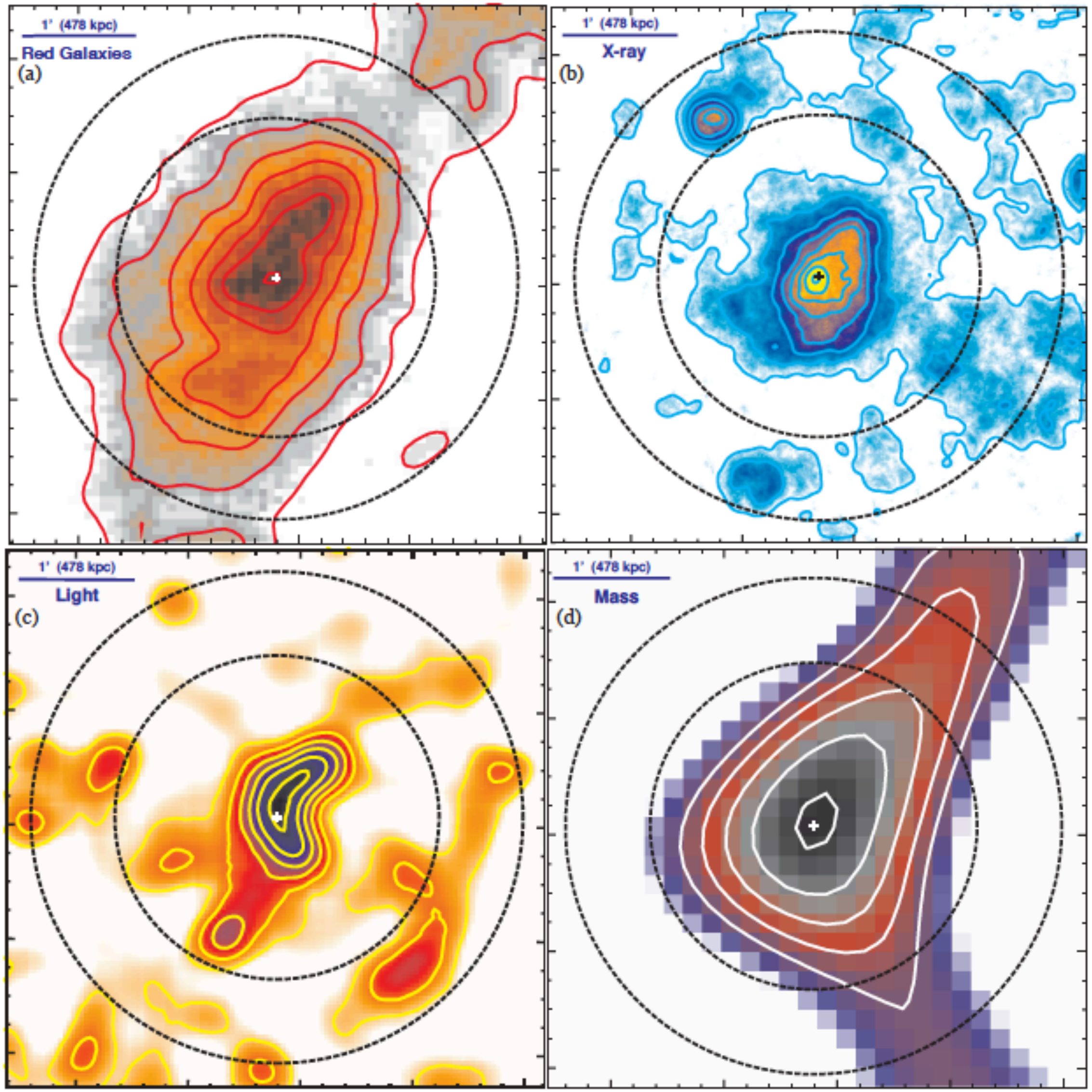
Multi-component View inside R_{200}

Red Galaxy Density Map

tracer particles

Chandra X-ray SB

n^2



z-Band Light Density

M_{star}

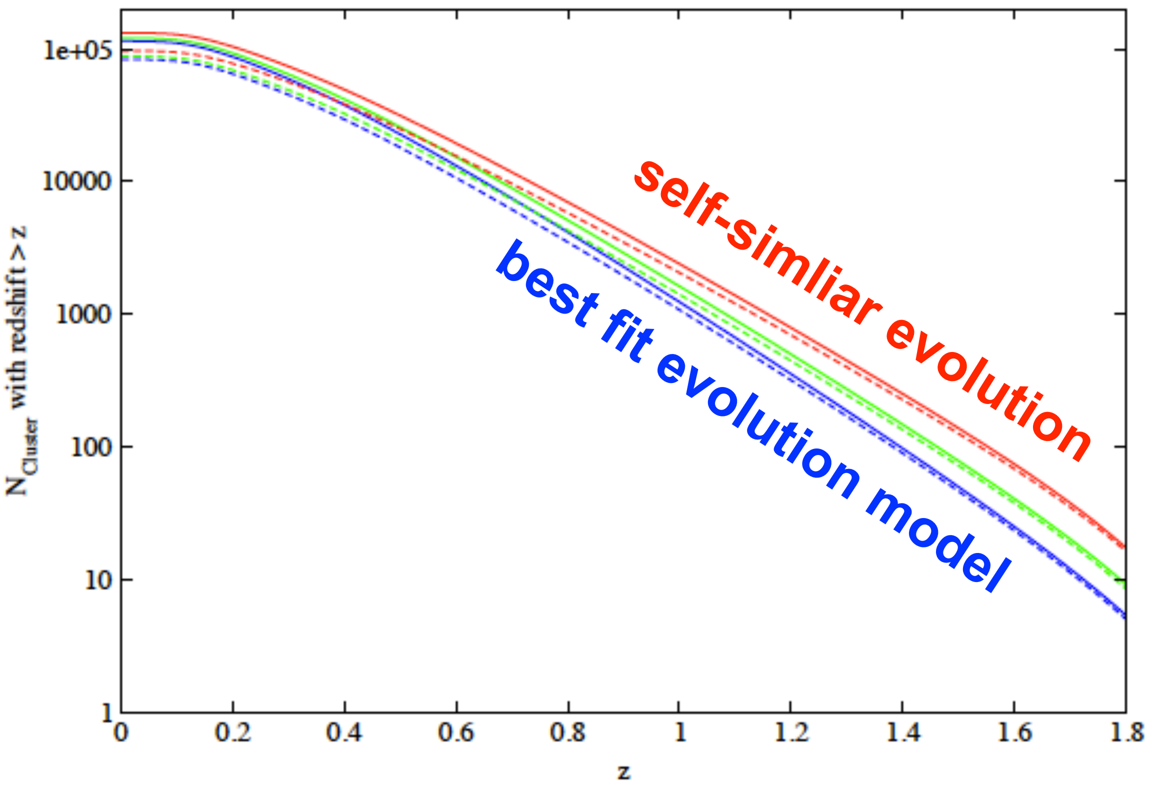
Weak Lensing Mass Map

M_{tot}

III. Prospects and Challenges for eROSITA Cluster Studies at z>1

Distant Cluster Expectations for eROSITA

N(>z) clusters with ≥100 counts



Best Fit Expectations

z	N(>z)	% of all clusters
z>0.8	3500	4.2
z>1.0	**1100**	**1.3**
z>1.2	300	0.4
z>1.4	**90**	**0.1**
z>1.6	20	0.03

Reichert et al. 2011, in press, arXiv:1109.3708

Distant Cluster Detectability with eROSITA

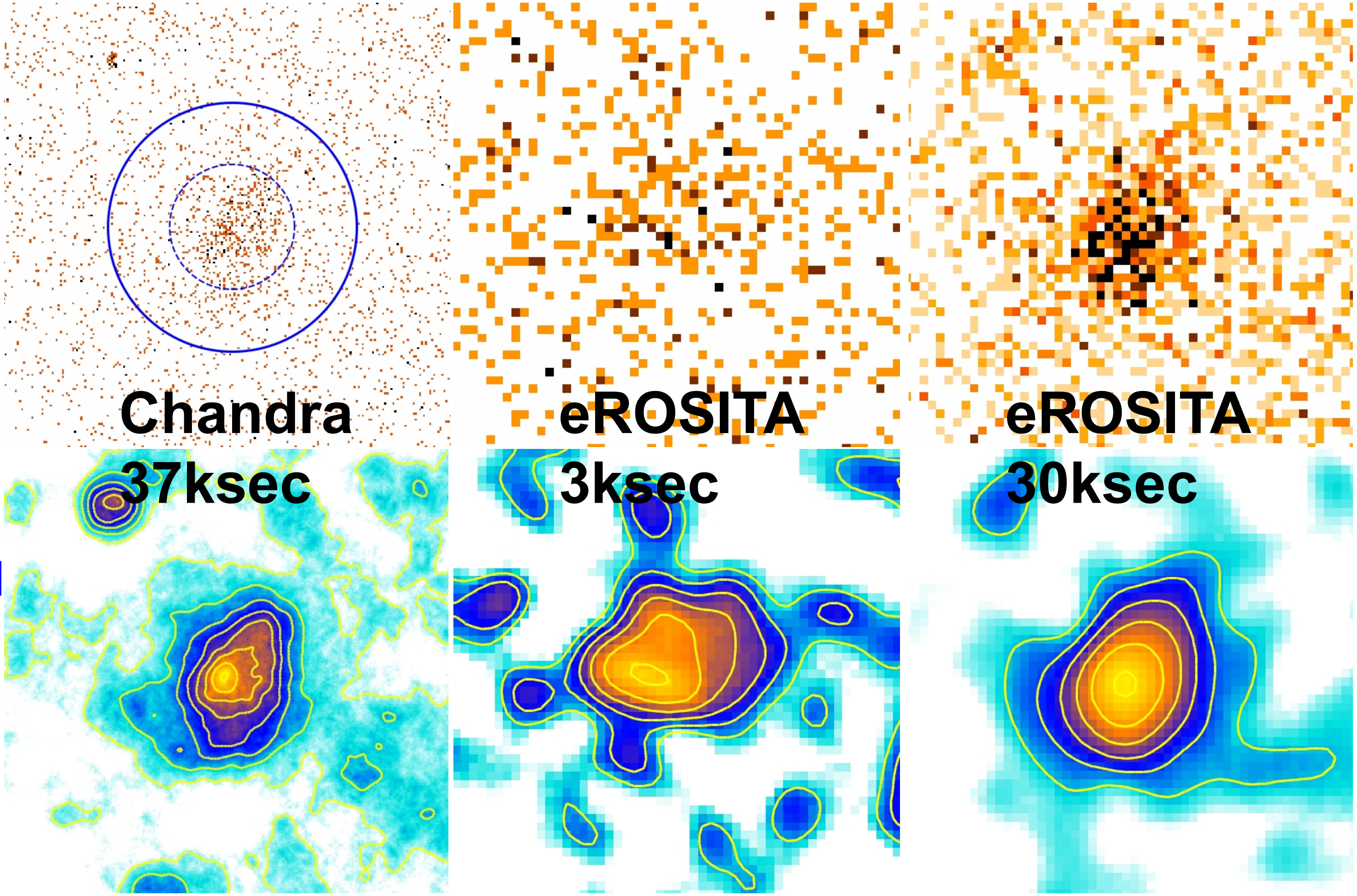
all sky survey detectability as extended X-ray source

The Chandra-eROSITA Image Simulator

goal: build up a distant cluster 'mock' data base for eROSITA performance tests based on real observations, i.e. with proper cluster structure and AGN contamination

raw photon image 3.5'x3.5'

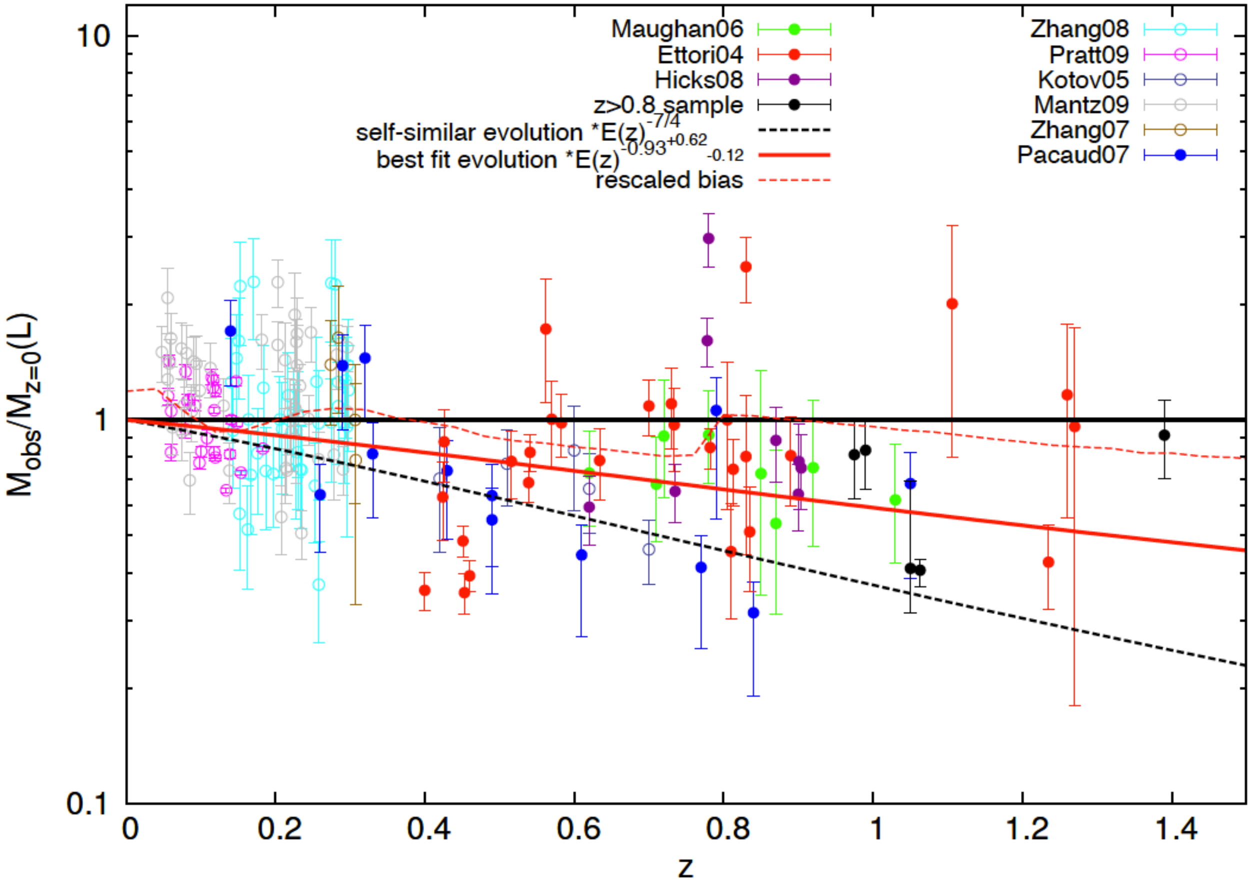
smoothed X-ray image 3.5'x3.5'



developed by Martin Mühlegger

Luminosity-based Mass Estimates at z>0.8

$$M = (1.64 \pm 0.07) \cdot (L_X[10^{44} \text{erg s}^{-1}])^{0.52 \pm 0.03} \cdot E(z)^{-0.90^{+0.35}_{-0.15}} 10^{14} M_{\odot}$$

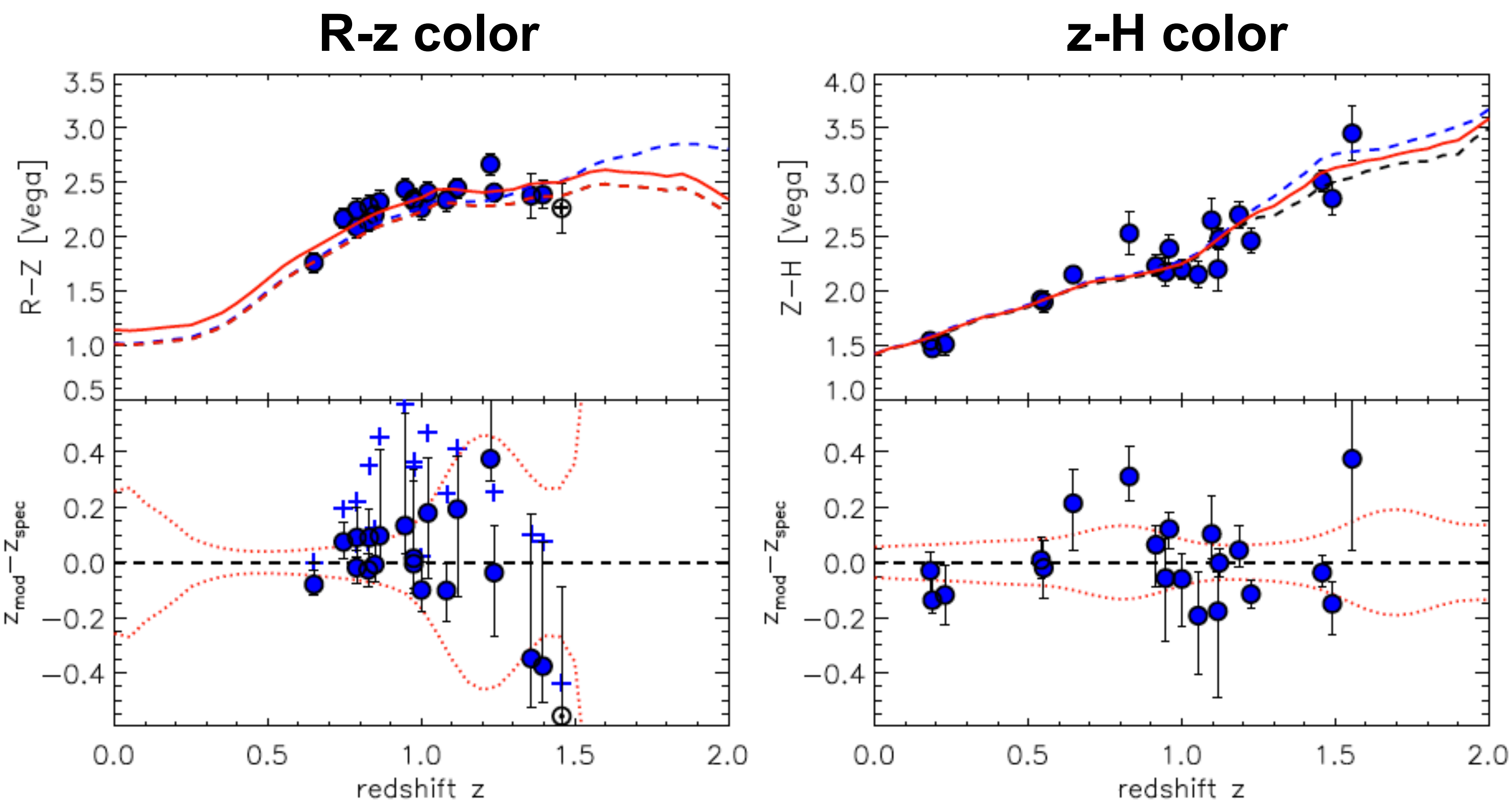


good L_X measurements currently allow mass estimates with **±30% uncertainty** **(using the local intrinsic scatter)**

to be improved for eROSITA applications

Reichert et al. 2011, in press, arXiv:1109.3708

Photometric Cluster Identification and Color-based Redshift Estimation out to z≥1.5

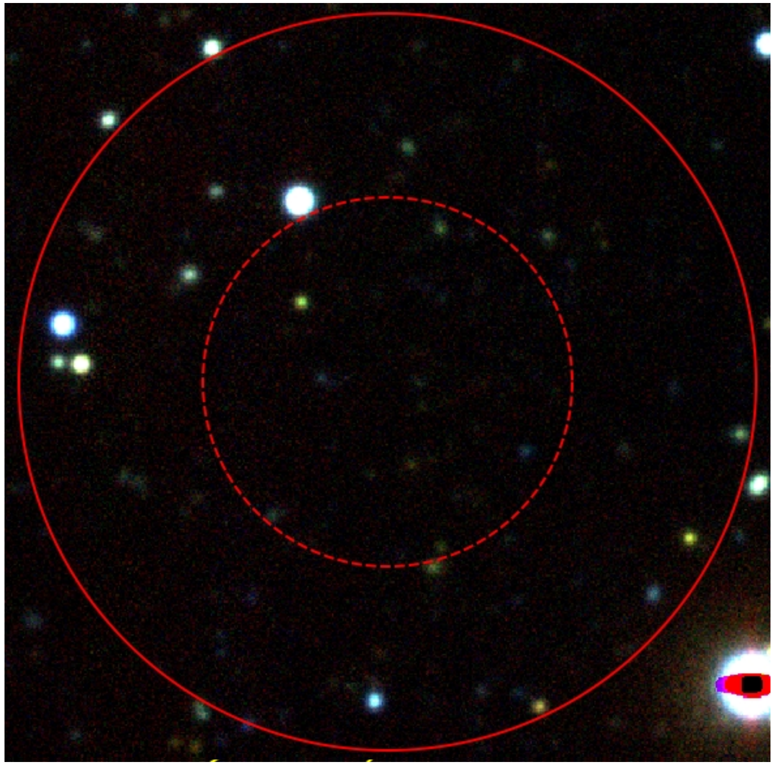


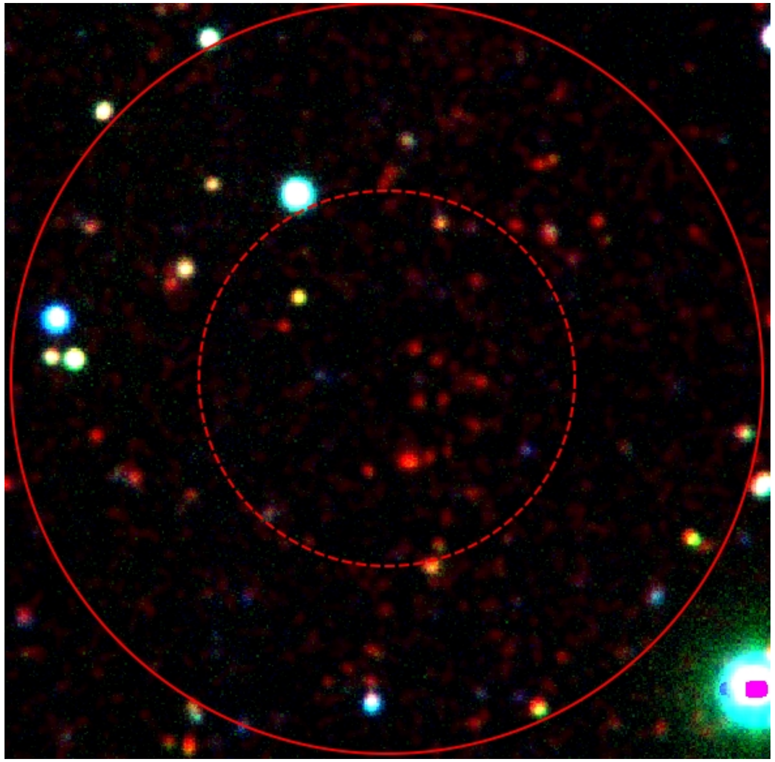
Fassbender et al. 2011, on the arXiv soon

The Need for Near-Infrared Data at z>1.2

characteristic L* magnitudes at z=1.5:

R_{AB}=25.9, I_{AB}=24.2, z_{AB}=23.8, J_{AB}=21.9, H_{AB}=21.3, Ks_{AB}=20.8





r_{lim}~23.9 mag
i_{lim}~23.6 mag
z_{lim}~22.3 mag

+H_{lim}~22.4 mag (21.0 Vega)

z=1.34

eROSITA z>1 Cluster Challenge Overview

Task	Challenge	Challenge Level (1-5)
source detection of extended sources	need purity levels >99%, every 1% impurity yields ~1000 spurious sources	+++++
optical and NIR imaging follow-up with 4m+ telescopes	deep, efficient data acquisition and reduct. with accurate color-based z-estimates out to z~1.6 for several 1000 sources	+++
spectroscopic follow-up (8m+ tel.)	redshift measurements for hundreds of clusters up to z~1.6	+++
mass estimates from M-L_X scaling relation	availability of an accurately calibrated M-L_X relation up to z~1.6	++
completeness, contamination & bias evaluation	characterization of AGN contamination effects on detection efficiency and L_X and T_X biases	+++
deep X-ray follow-up observations	deep (Chandra) X-ray data for a suffici-ently large sub-sample to allow a detailed characterization of z>1 eROSITA clusters	++++

Summary & Conclusions

1. The XMM-Newton Distant Cluster Project has compiled the largest sample of high-z X-ray clusters to date and is hence an important pathfinder survey for high-z eROSITA applications

2. A first XDCP sample of 22 clusters at $0.9<z<1.6$ is about to be published (17 at $z \geq 1$ and 7 at $z>1.3$) with a median system mass of $2 \times 10^{14} M_{sun}$

3. The currently most realistic eROSITA forecasts predict about 1100 clusters at $z>1.0$ and 90 systems at $z>1.4$ in the full survey with a minimum of 100 counts each

4. All-sky eROSITA cluster identifications at the highest redshifts will inevitably have to rely on an X-ray source extent criterion, which results in a major challenge for the cluster detection algorithms

5. Efficient ground-based follow-up techniques for cluster identifications out to at least $z \sim 1.6$ are now available and X-ray luminosity-based mass estimates at high-z are becoming reliable