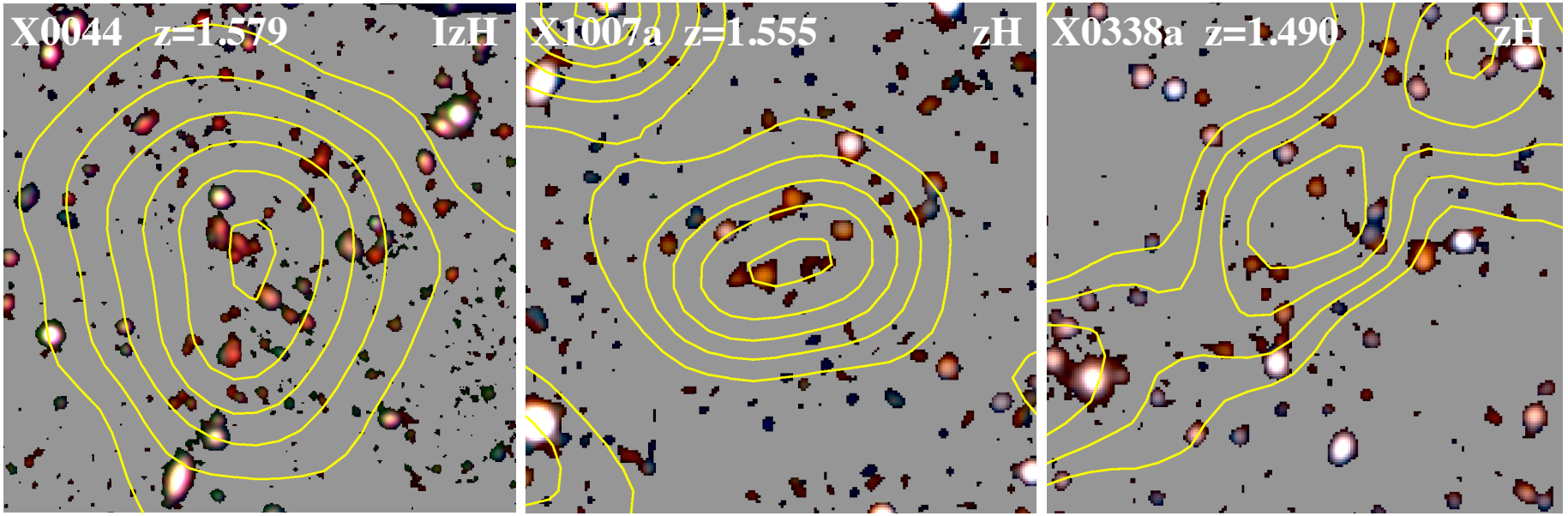
XMM-Newton's View of the Highest Redshift X-ray Luminous Galaxy Clusters



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X-ray Universe 2011, Berlin, 29. June 2011

Agenda

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

II. The XMM-Newton Distant Cluster Project

III. The X-ray Cluster Population at z>1.3

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

Simulated Formation of a Massive Galaxy Cluster

Dark Matter (grav. lensing)	Gas Density (X-ray)	Temp. (X-ray)	kin. SZE (not yet)	therm. SZE (mm)	Gas Shocks (X-ray)

z=2
t_{lb}=10.2 Gyr

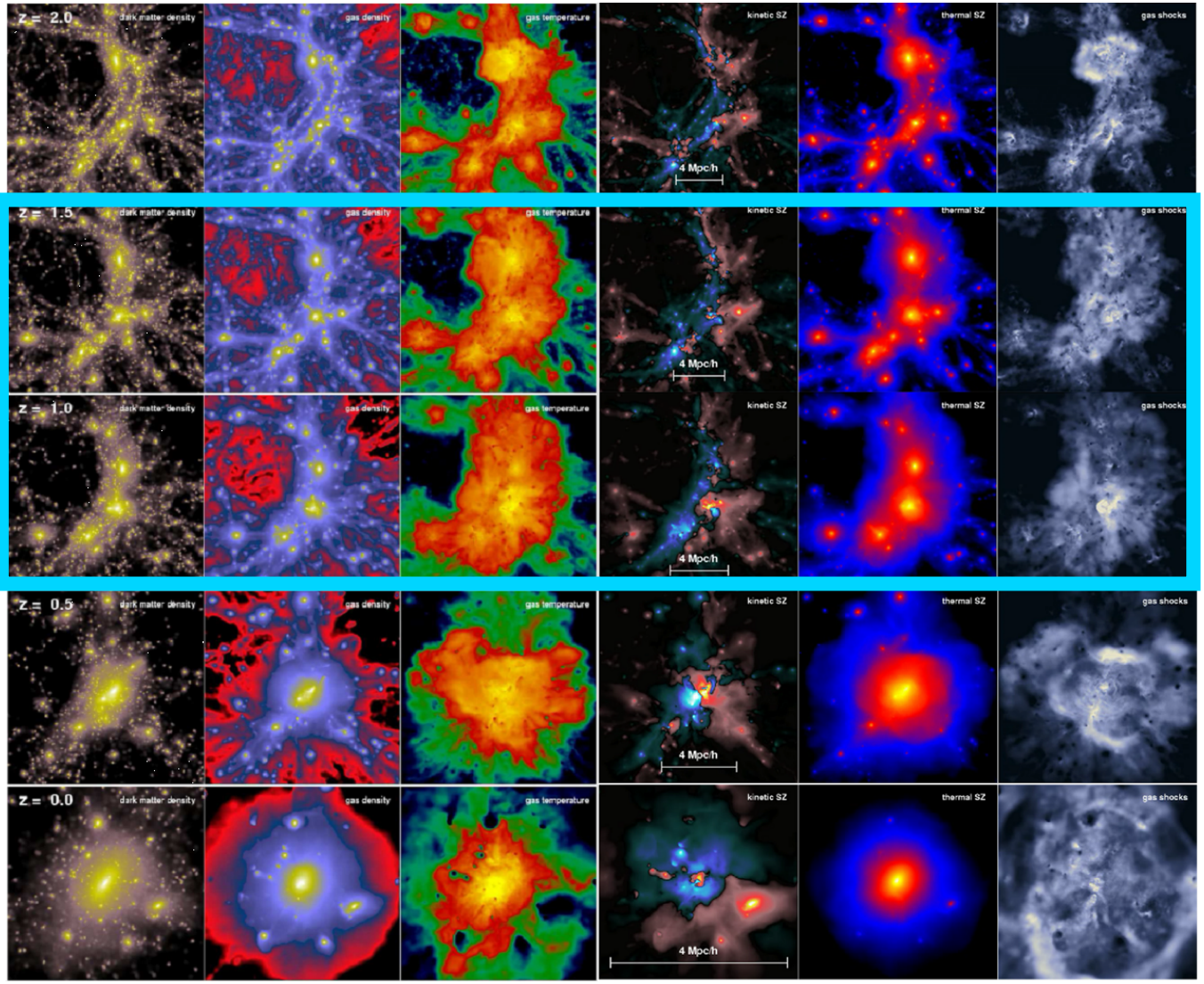
z=1.5
t_{lb}=9.3 Gyr

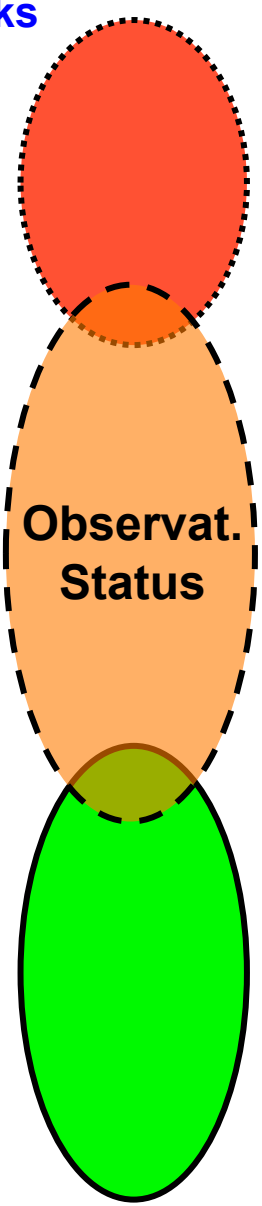
z=1.0
t_{lb}=7.7 Gyr

$z_{1/2}$=0.78
$t_{1/2}$=6.7 Gyr

z=0.5
t_{lb}=5.0 Gyr

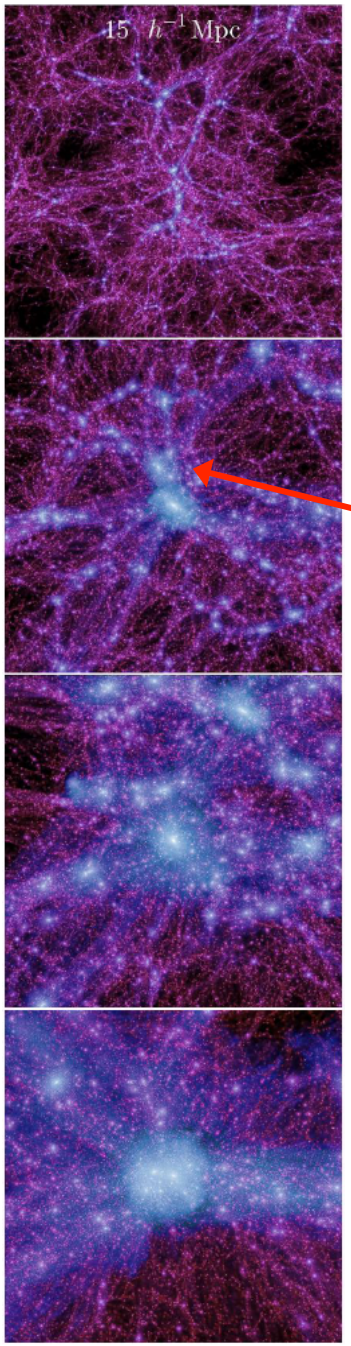
z=0
t_{lb}=0 Gyr

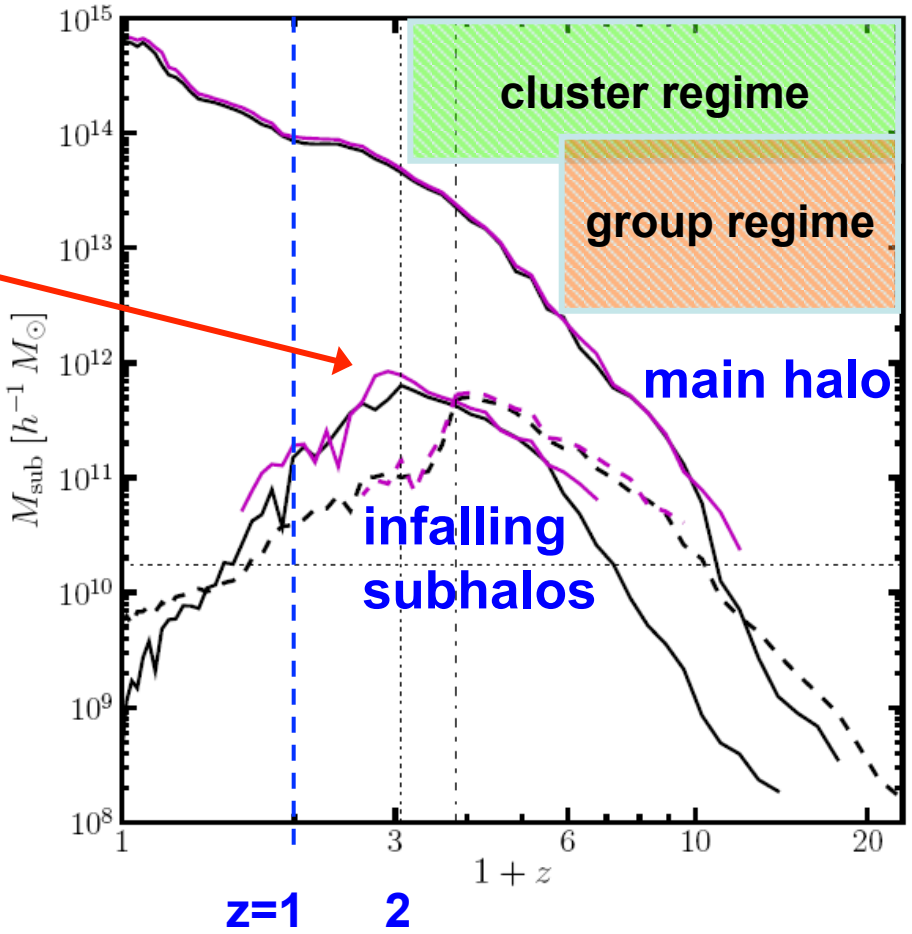




http://www.mpa-garching.mpg.de/galform/data_vis/index.shtml

Simulated mass evolution of a single massive galaxy cluster from the Millennium-II Simulation



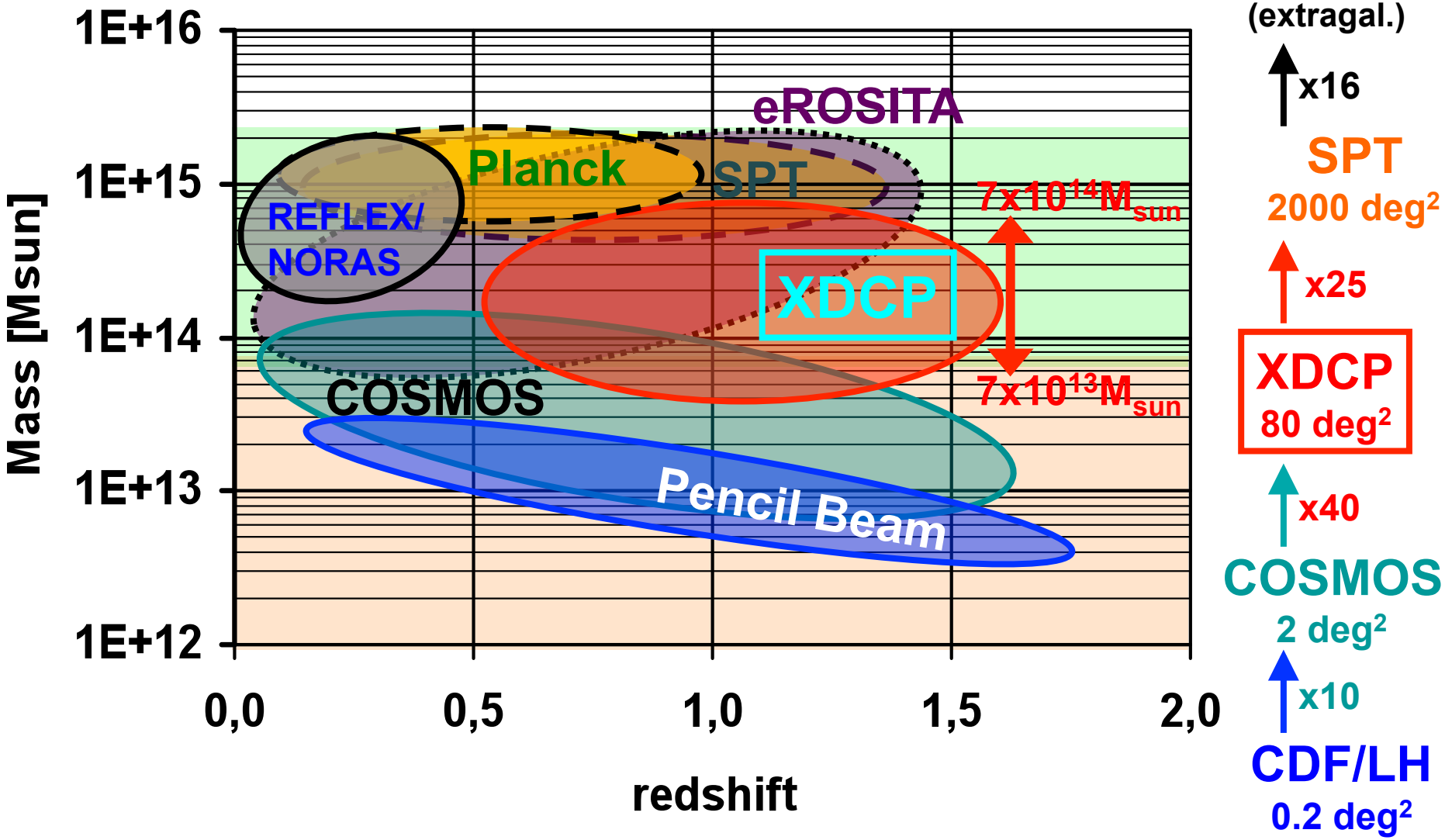


the total mass of the main halo has grown by more than a factor of 10 since z=2

Boylan-Kolchin et al. 2009

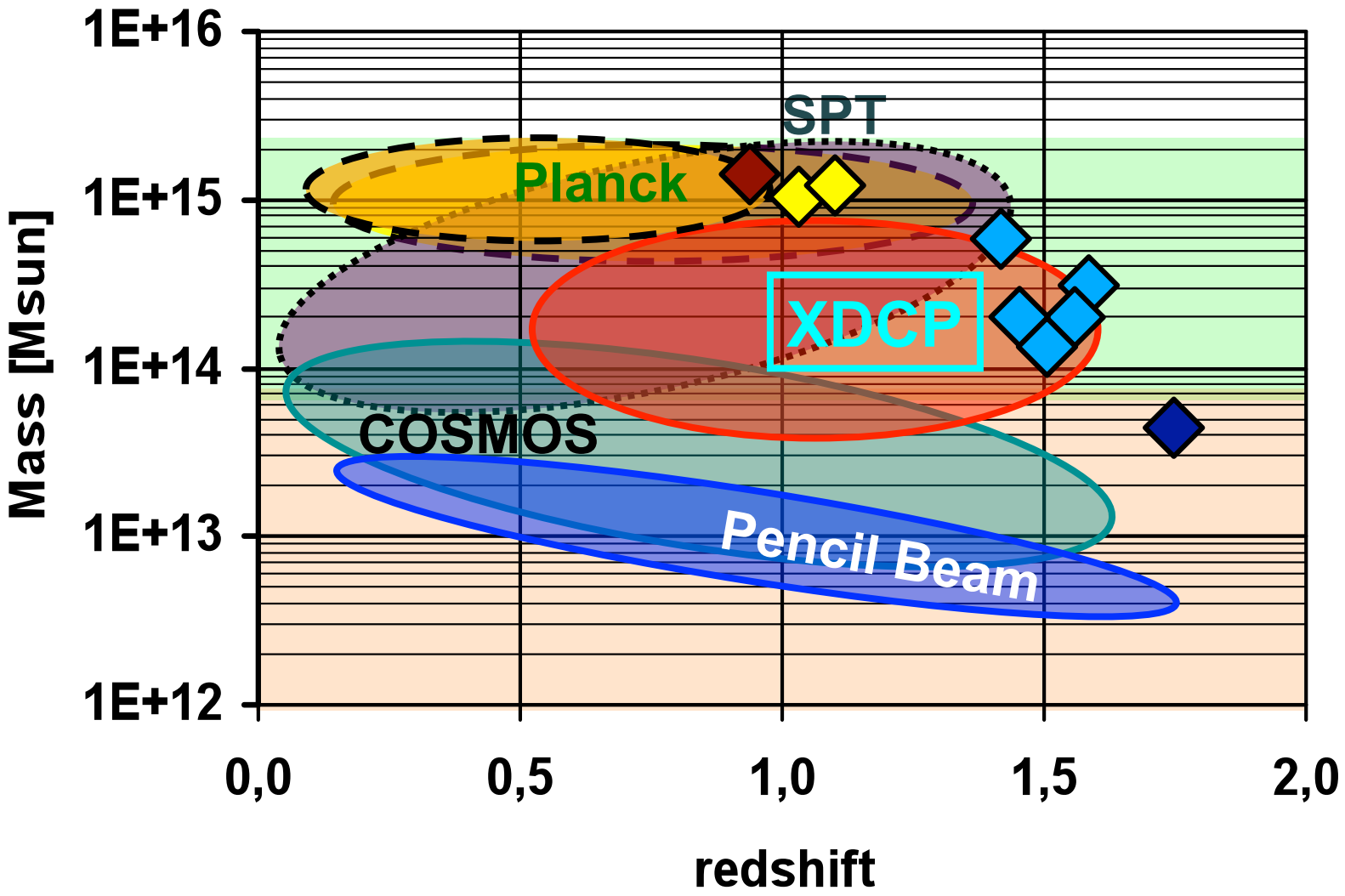
Galaxy Cluster Surveys based on ICM Signature

(Incomplete) Schematic View



Galaxy Cluster Surveys based on ICM Signature

Status of known clusters at highest z



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	0.6	Tanaka+10, 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	**XMMUJ 0338+0021**	**Xray**	**1.1**	**1.2**	Nastasi+11
1.49	ISCS J1432.4+3250	MIR	3.5	2.5	Brodwin+10
1.46	**XCSJ2215.9-1738**	**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 XMM-Newton Distant Cluster Project

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 80deg^2
- follow-up imaging data for >80% 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 (and for next 10 years)

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

XDCP Search Method for Distant Galaxy Clusters

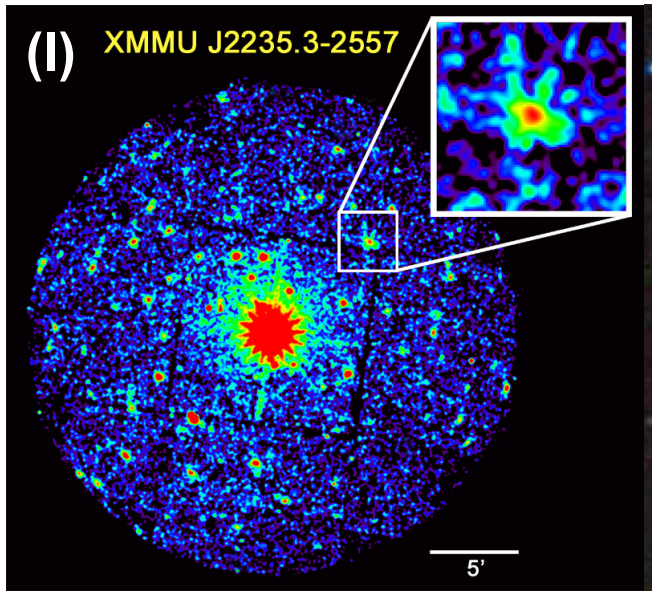
I) identification of (weak) extended X-ray sources in the XMM-Newton archive

II) imaging confirmation of a galaxy overdensity & red-sequence redshift estimate

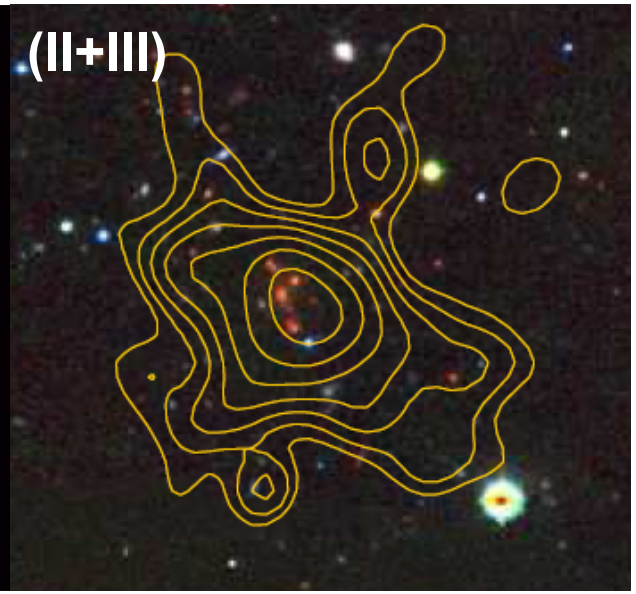
III) spectroscopic redshift determination with VLT FORS2

IV) detailed multi-wavelength follow-up of the most interesting clusters

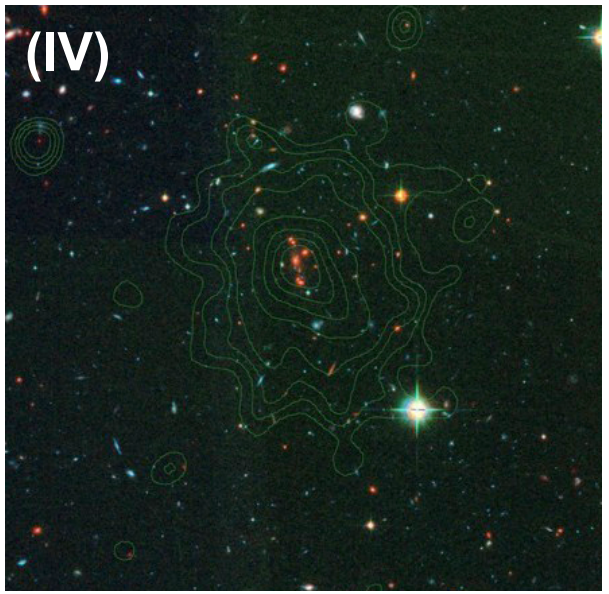
Example: XMMU J2235.3-2557 at z=1.39



XMM field-of-view



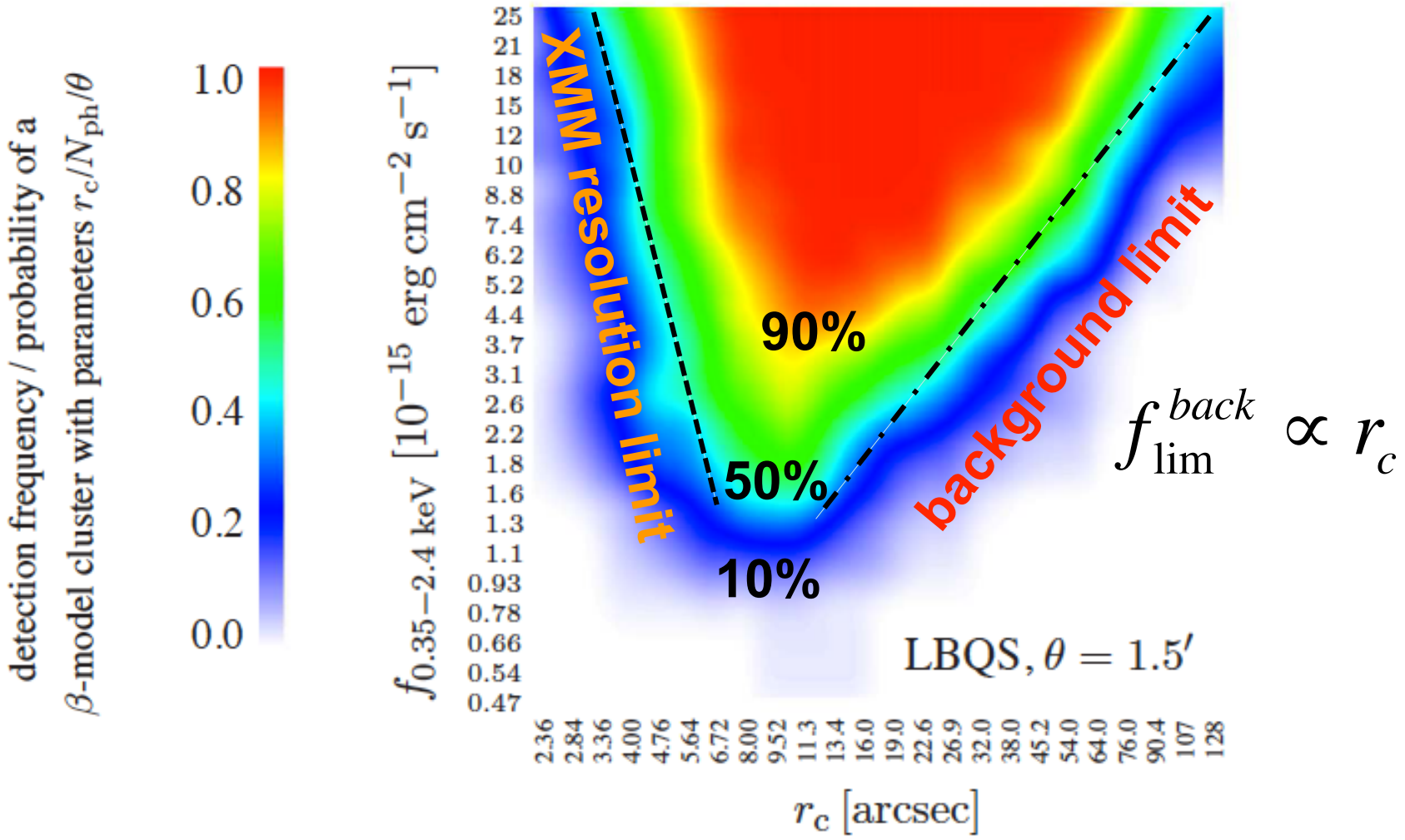
XMM X-ray contours
+RzK band color composite



Chandra X-ray contours
+ HST(i,z)+VLT(K) image

Mullis et al. 2005, Rosati et al. 2009

Accessible flux-core radius parameter range for high-z cluster detections with XMM

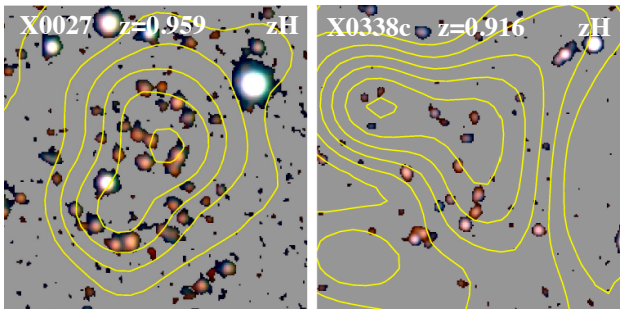


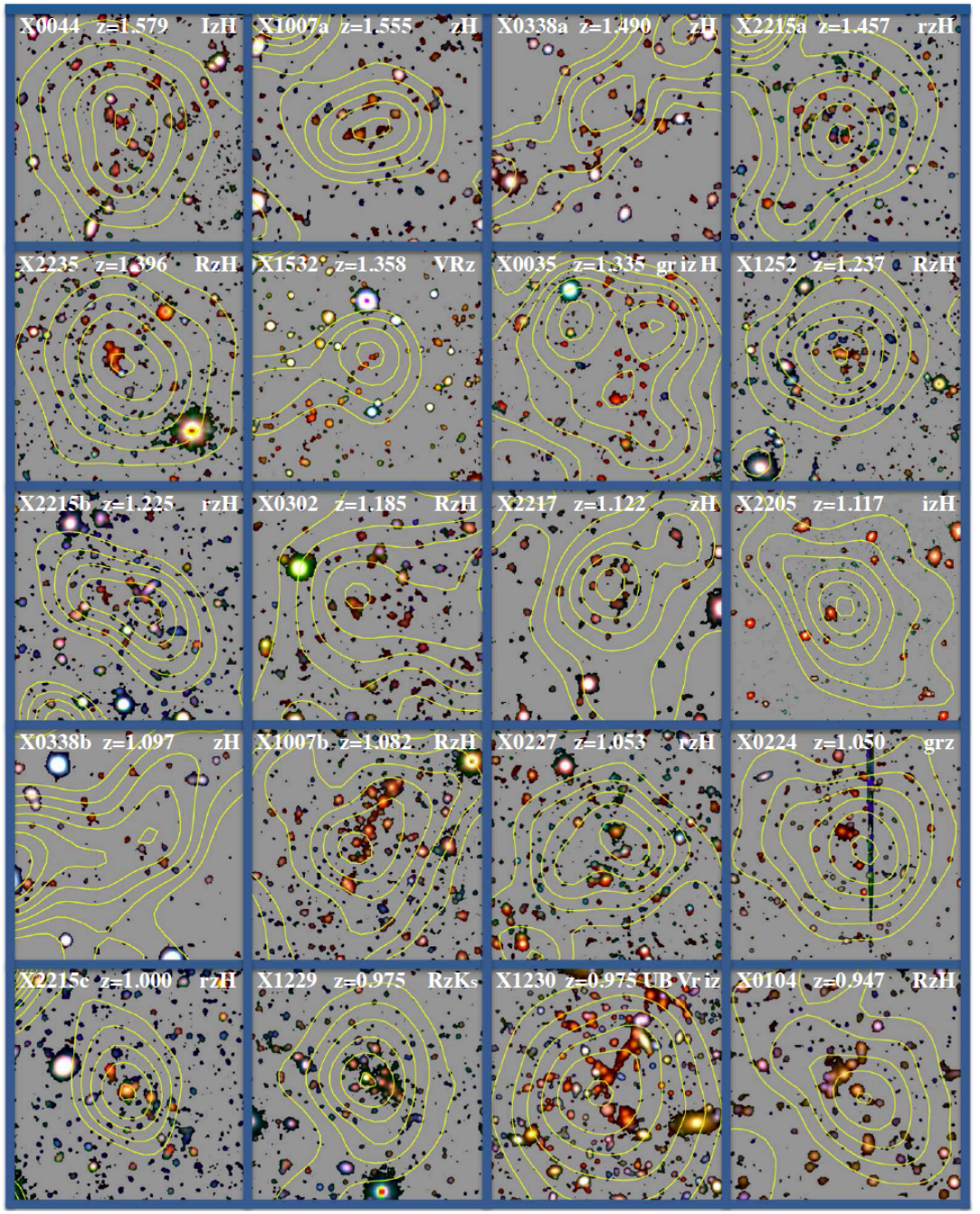
M. Mühlegger, PhD thesis, 2010

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

17 clusters at z≥1.0

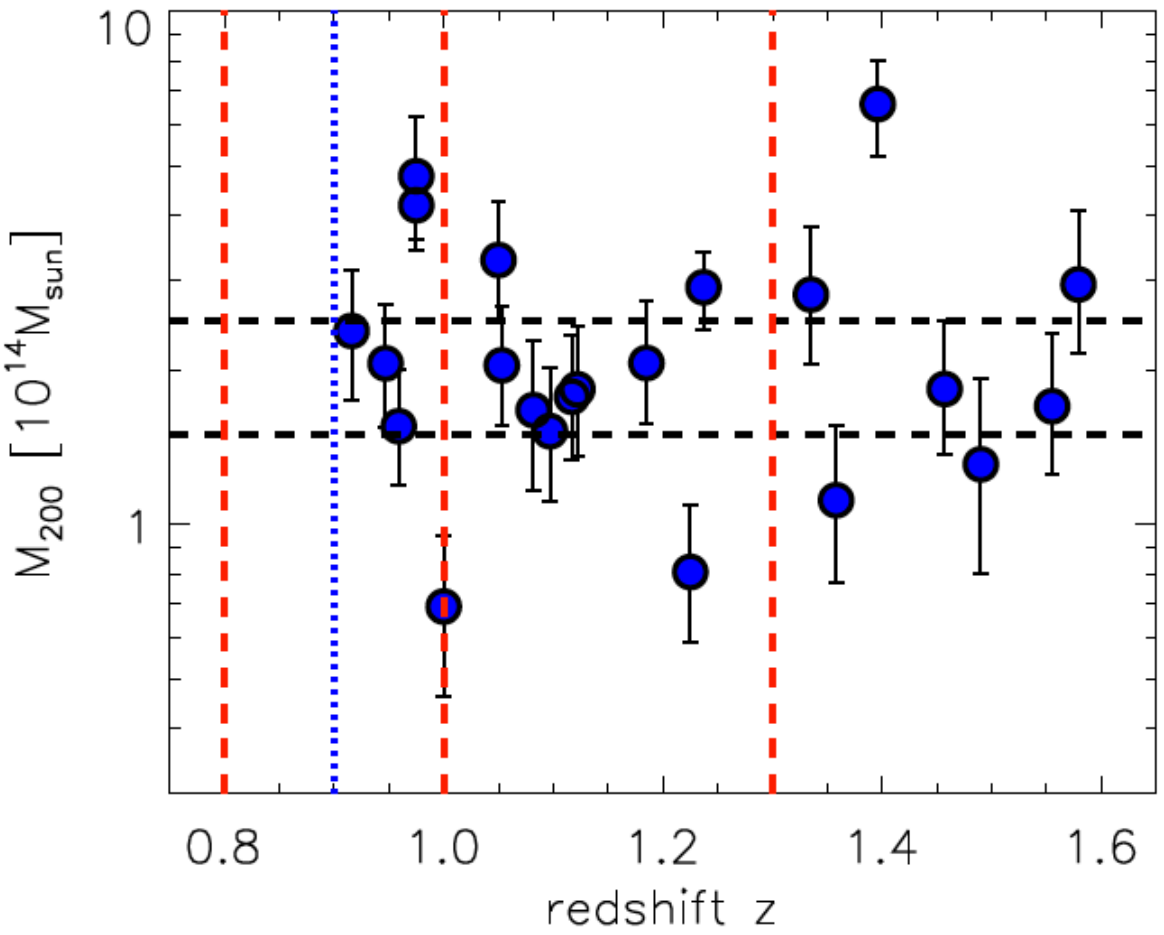
7 clusters at z>1.3





Fassbender et al., to be subm.

Mass vs Redshift Distribution of XDCP Clusters

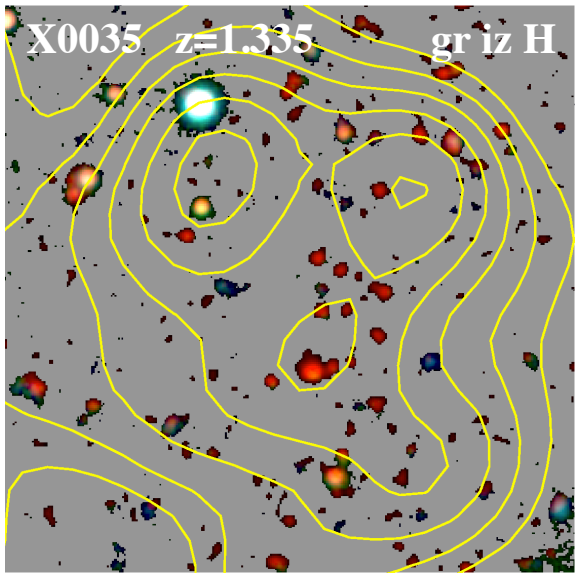


median cluster mass of sample $2 \times 10^{14}\ M_{sun}$

Fassbender et al., to be subm.

III. The X-ray Cluster Population at z>1.3

X-ray Clusters at z~1.35



SpARCS/XMMU J0035.8-4312 at z=1.335

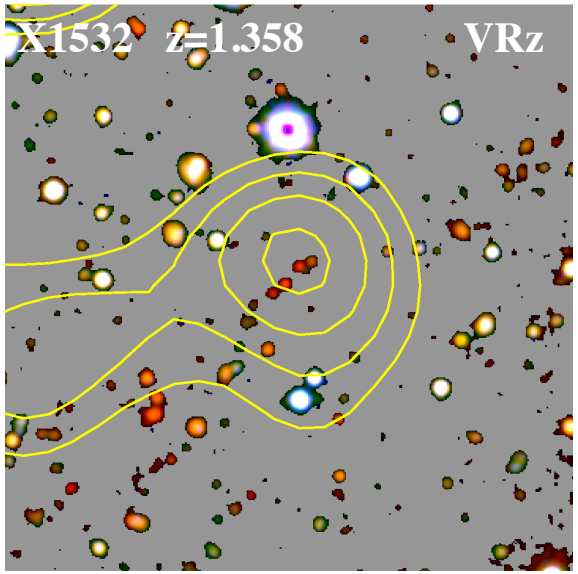
Wilson et al. 2009

Fassbender, Böhringer, Nastasi et al., to be subm.

$L_{X,bol} \sim 3.5 \times 10^{44}$ erg/s

$T_X \sim 4.5$ keV

$M_{200} \sim 2.5 \times 10^{14} M_{sun}$



1.5'x1.5'

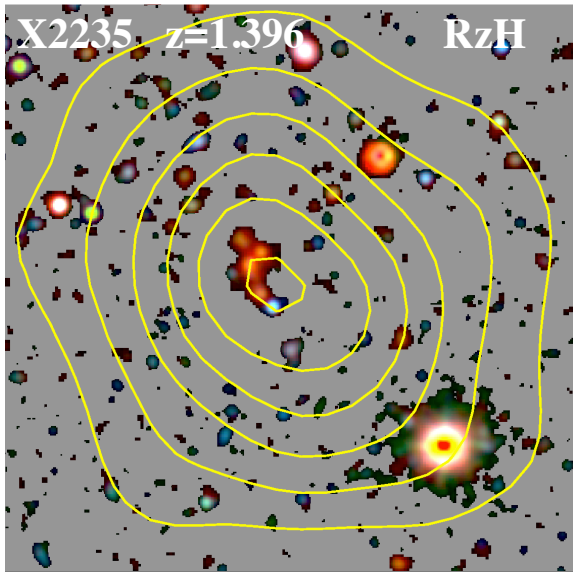
XMMU J1532.2-0837 at z=1.358

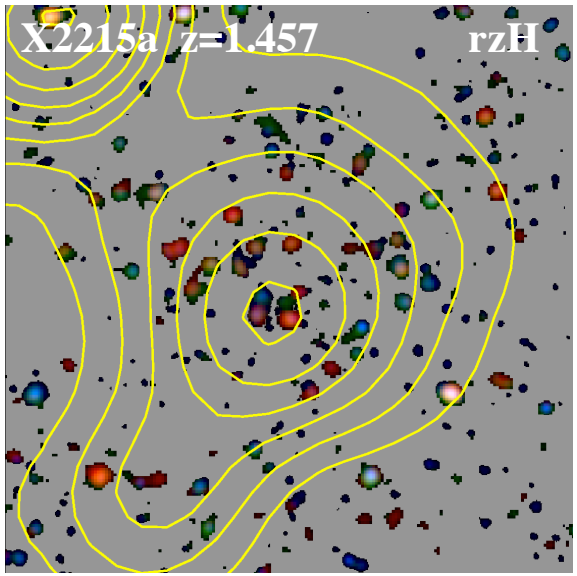
Suhada, Fassbender, Nastasi et al., 2011, A&A, 530, A110

$L_{X,bol} \sim 0.8 \times 10^{44}$ erg/s

$M_{200} \sim 1.1 \times 10^{14} M_{sun}$

X-ray Clusters at z~1.45





1.5'x1.5'

XMMU J2235.3-2557 at z=1.396

Mullis et al. 2005, ApJ, 623, L85
Rosati et al. 2009, A&A, 508, 583
Jee et al. 2009, ApJ, 704, 672
Strazzullo et al. 2010, A&A, 524, A17

$L_{X,bol} \sim 10 \times 10^{44}$ erg/s
$T_X \sim 8.6$ keV
$M_{200} \sim 6.6 \times 10^{14} M_{sun}$

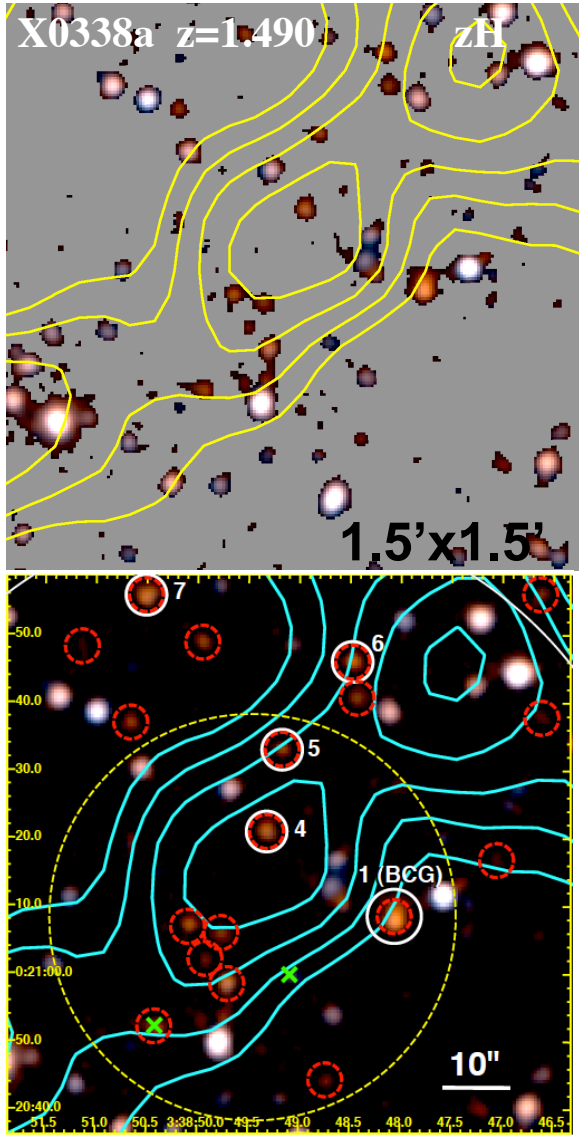
XMMXCS J2215.9-1738 at z=1.457

Stanford et al. 2006
Hilton et al. 2007, 2009, 2010
Hayashi et al. 2010, 2011

$L_{X,bol} \sim 2.2 \times 10^{44}$ erg/s
$T_X \sim 4.1$ keV
$M_{200} \sim 1.9 \times 10^{14} M_{sun}$

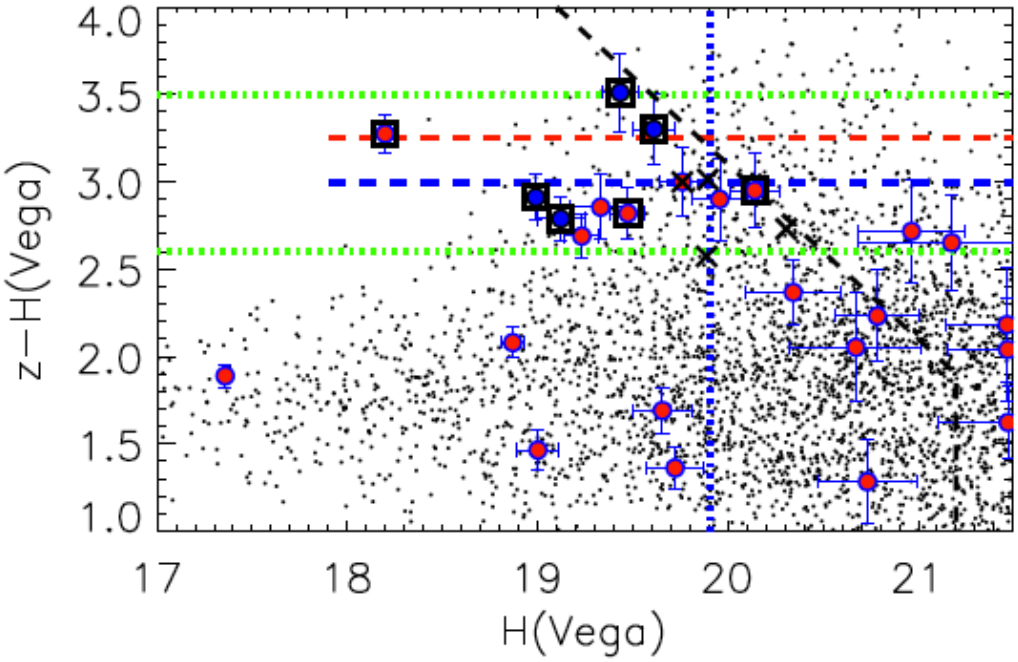
XMMU J0338.8+0021 at z=1.490

Nastasi, Fassbender, Böhringer et al. 2011, A&A, in press, arXiv:1106.5784



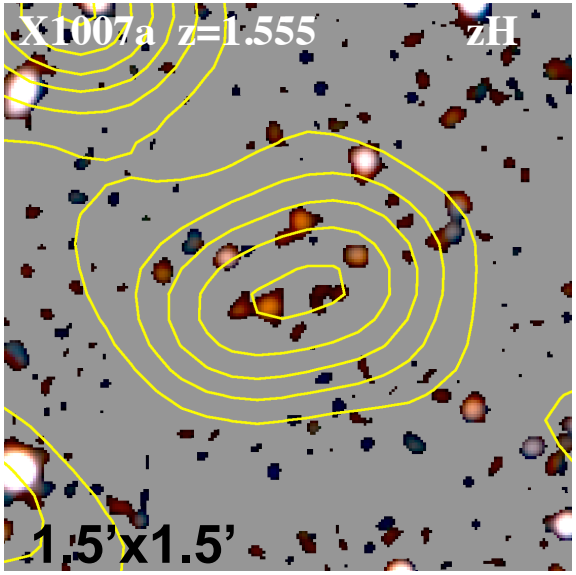
$L_{X,bol} \sim 1.1 \times 10^{44}$ erg/s

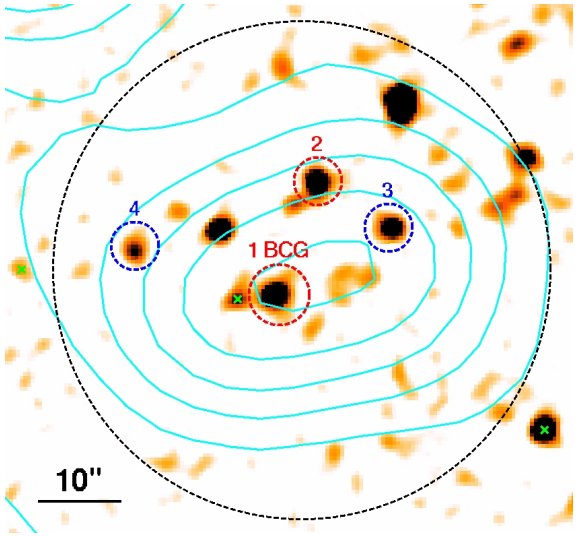
$M_{200} \sim 1.2 \times 10^{14} M_{sun}$



XMMUJ1007.3+1237 at z=1.555

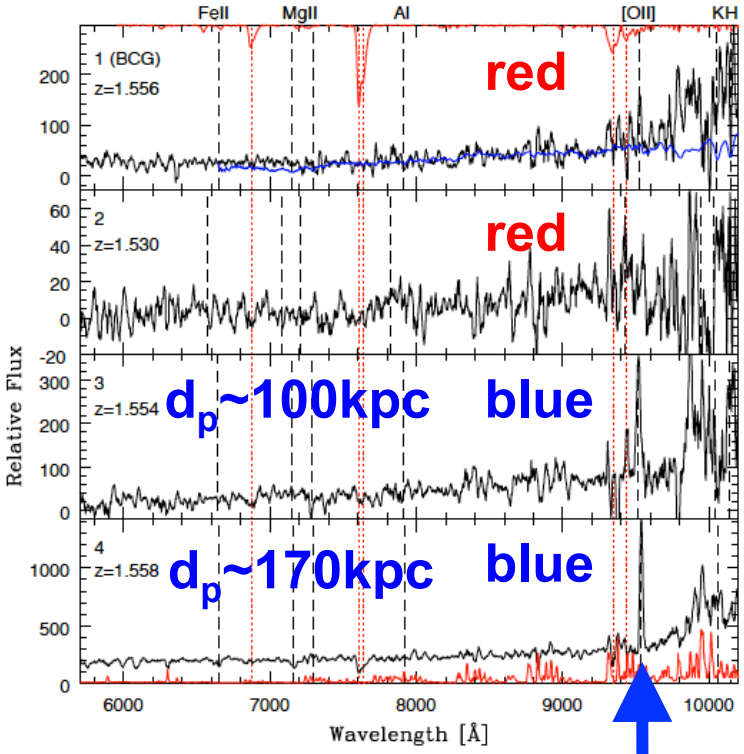
Fassbender, Nastasi, Böhringer et al. 2011, A&A, 527, L10





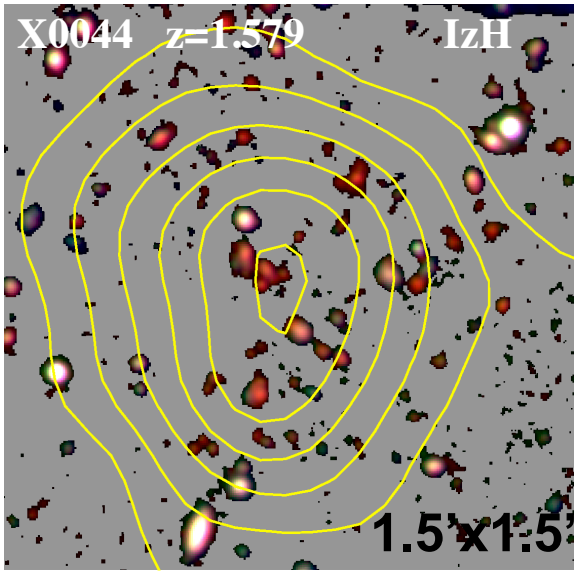
$L_{X,bol} \sim 2.1 \times 10^{44}$ erg/s

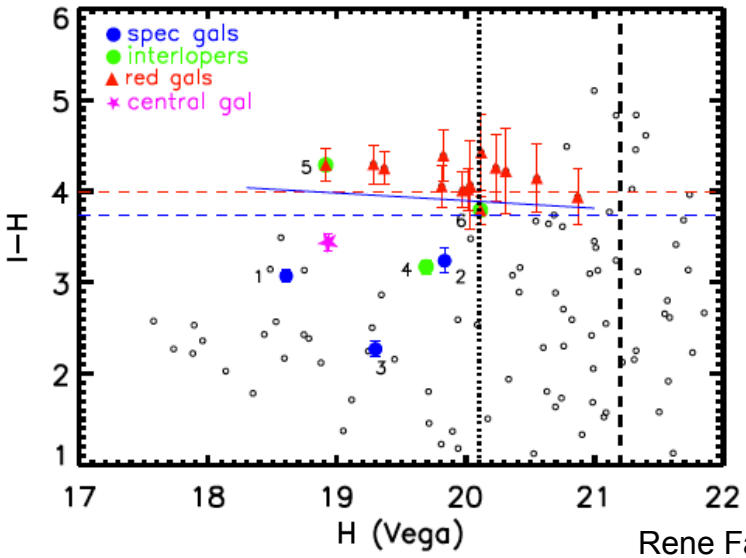
$M_{200} \sim 1.7 \times 10^{14} M_{sun}$



XMMUJ0044.0-2033 at z=1.579

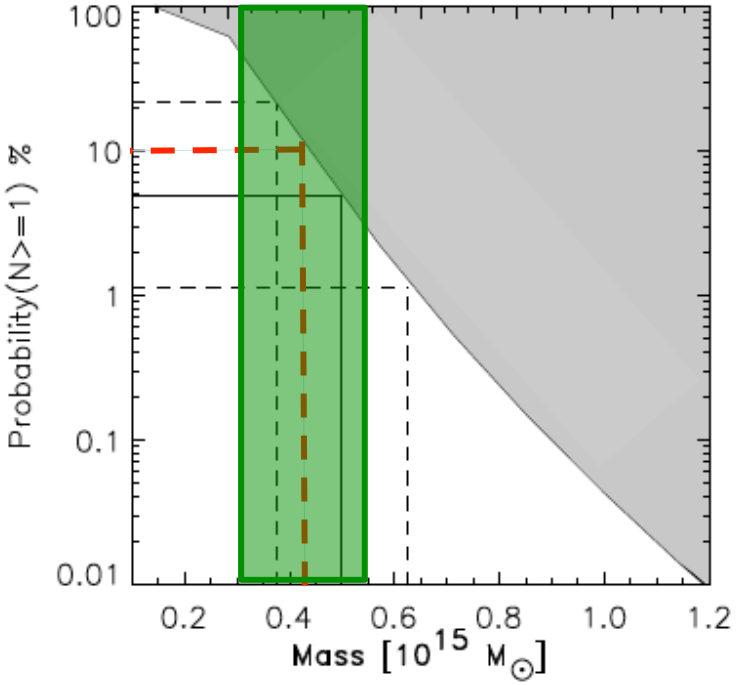
Santos, Fassbender, Nastasi, et al. 2011, A&A, in press, arXiv:1105.5877





$L_{X,bol} \sim 6.1 \times 10^{44}$ erg/s

$M_{200} \sim (3\text{-}5) \times 10^{14}\ M_{sun}$



the 2nd least likely cluster in XDCP after XMMU J2235-2557

Summary & Conclusions

1. XMM-Newton is the unrivaled workhorse for (serendipitously) detecting X-ray luminous high-z galaxy clusters out to z>1.5

2. The XMM-Newton Distant Cluster Project has compiled the largest sample of high-z X-ray clusters to date; a first catalog of 22 systems at 0.9<z<1.6 is about to be published with 17 at z≥1 and 7 at z>1.3

3. The cluster sample has a median system mass of $2 \times 10^{14} M_{sun}$ and spans a wide mass range of $(0.7\text{-}7) \times 10^{14} M_{sun}$, which will allow cluster population studies as a function of system mass *and* redshift up to lookback times of 9.5 Gyrs

4. XMMU J0044.0-2033 at z=1.58 is the most massive cluster at z>1.5 currently known

5. At these redshifts the bright end of the cluster galaxy population is not yet fully developed and the cluster red-sequences appear to start dissolving

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