



# The XCS: from Photons to Cosmology

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# Overview

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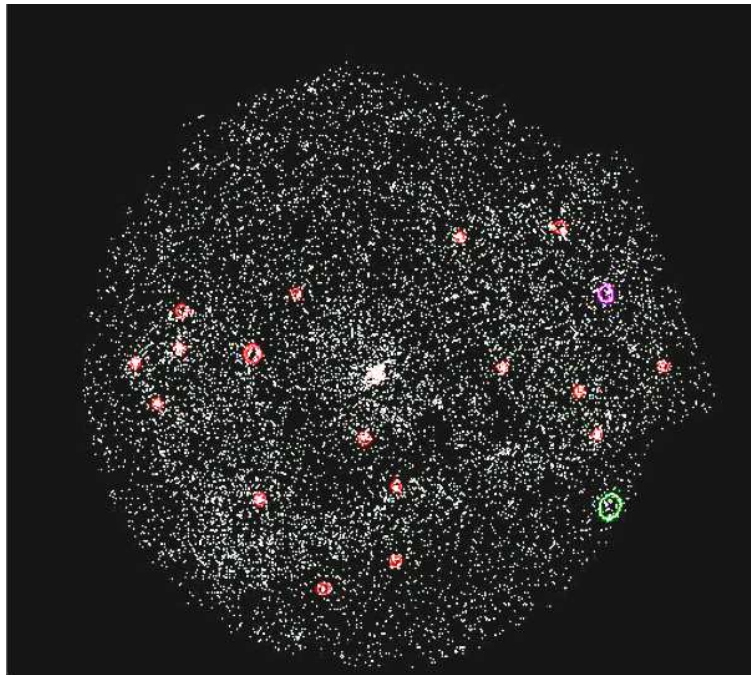
- The XMM Cluster Survey [XCS]
- Cluster detection
- Cluster classification
- Redshift estimates
- High redshift cluster J2215
- Scaling relations
- Cosmology

# XMM Cluster Survey [XCS]

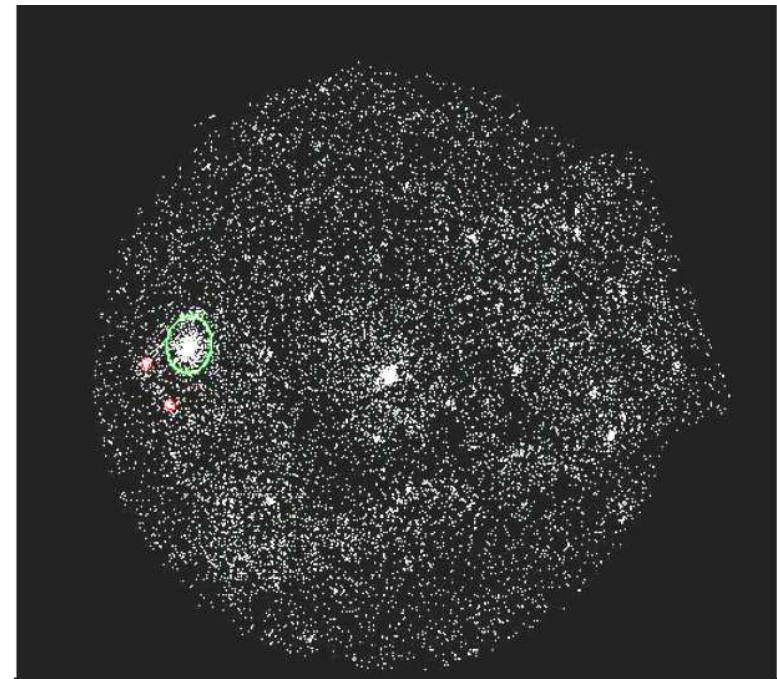
- The XCS
  - Archival pointings
  - Serendipitous detections
  - 170 sq. deg. present
  - 500 sq. deg. total
  - $0.1 < z < 2$
  - Currently: 1847  
*all* XCS
  - Expect  $\approx 2.10^3$   
 $_{500}$  XCS



# Detecting clusters



Detecting real clusters



Detecting simulating clusters

- Color key
  - Extended sources, Green ellipses
  - Point sources, red circles
  - Unsure, Pink circles

From simulations we can recover our selection function.

# Cluster classification

- Cluster zoo
  - SDSS optical images
  - Centred on X-ray ra,dec
  - 610 XCS extended sources
  - Optical & X-ray overlays
  - X-ray photon density contours
  - 7 classification types
  - 9+ classifications

**XCS classification page**

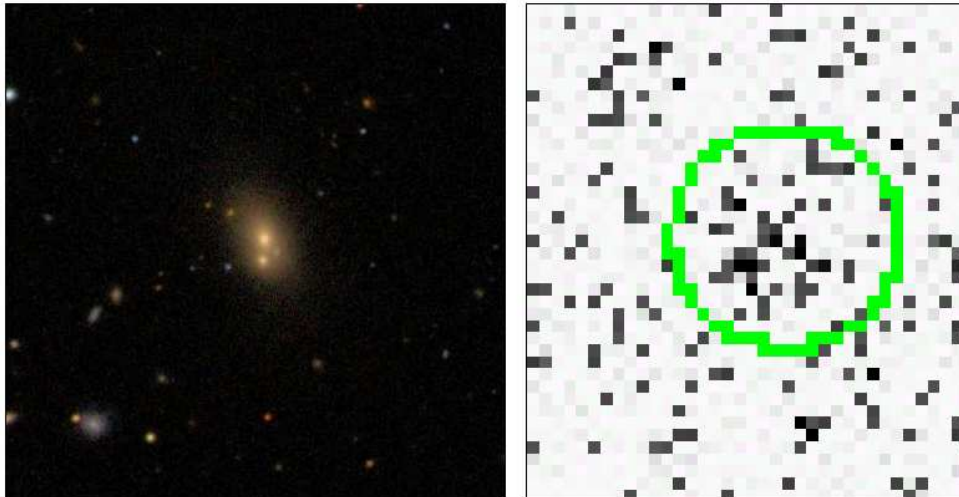
Please examine the figures found under the Optical&X-ray images and Mask data tabs, before making an ex classification decision, under the third tab. This session you have made 1 classifications. Your target is 30. Ther classifications since midnight last night. View the current [results here](#).

Optical&X-ray images   Mask data   Make your classification

**Optical and Xray images**

Scrolling down the page displays images of the extended sources to be classified at three magnifications in the x-ray. Simply moving [no need to click] your mouse over the contours: [\[on\]](#) and [\[off\]](#) links show and hide the contour. [\[inv\]](#) inverts the sdss image, and highlights photometric objects. The current x-ray image is shown with a **Green** ellipse around the extended source of interest as picked by the computer algorithm. The **Red** circles correspond to point sources.

Magnification 3by3 acrmns contours: [\[on\]](#) [\[inv\]](#) [\[off\]](#)

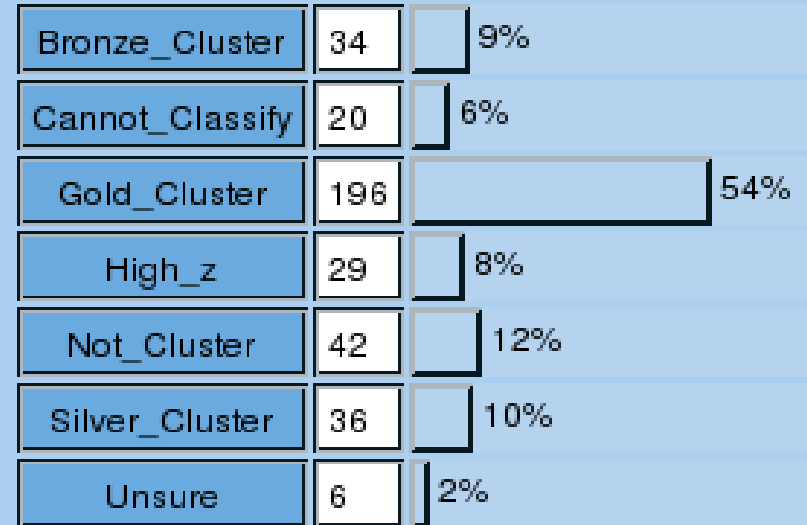


The screenshot shows the XCS classification interface. At the top, there are three tabs: 'Optical&X-ray images', 'Mask data', and 'Make your classification'. Below the tabs, the 'Optical and Xray images' section is active. It contains a paragraph of instructions and a set of two images. The left image is an optical image showing a cluster of galaxies. The right image is an X-ray image showing the same cluster with a green ellipse highlighting a source of interest. Above the images, there are links for 'Magnification 3by3 acrmns contours: [on] [inv] [off]'.

# Cluster classification

## ■ Results

- Gold sample
- High Z
- False detections
- Cuts improve sample



## Classification accuracy improvements

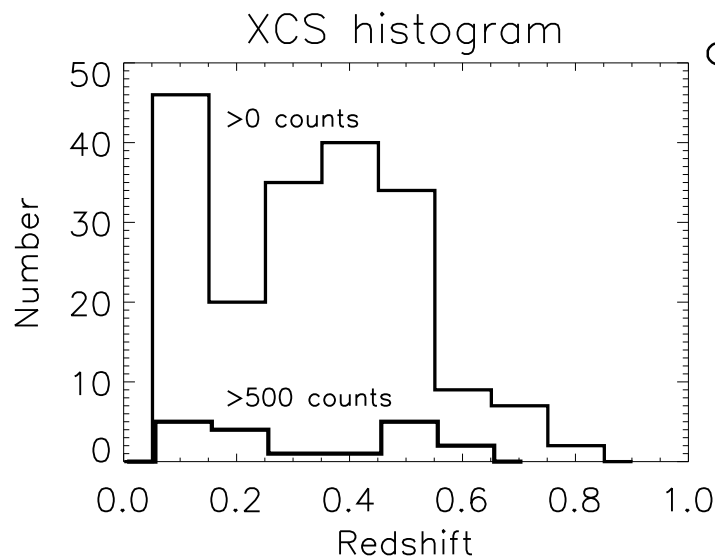
Soft Counts	% Gold Clusters	% All Clusters
> 0	18	55
> 200	41	77
> 500	54	81



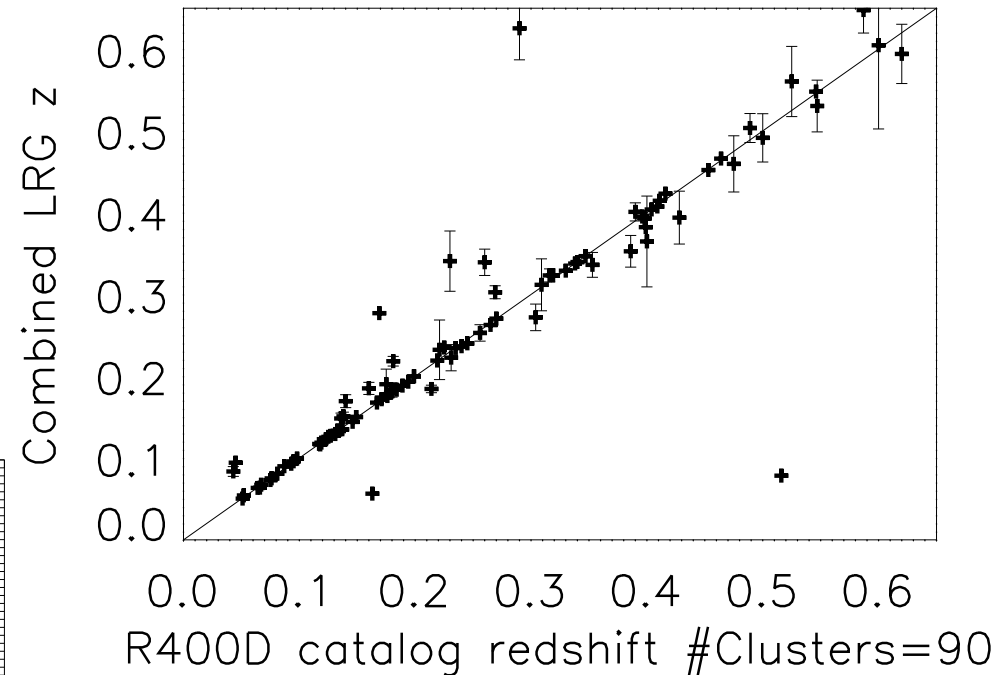
# Redshift estimates

Empirically, we see LRGs inhabit the central regions of clusters. Can we use archival LRGs to assign redshifts to X-ray detected clusters for free?

- *ROSAT*400 sq. deg.
- Spectroscopic redshifts
- Compare with SDSS LRGs
- Spec and Photo redshifts
- Good Agreement



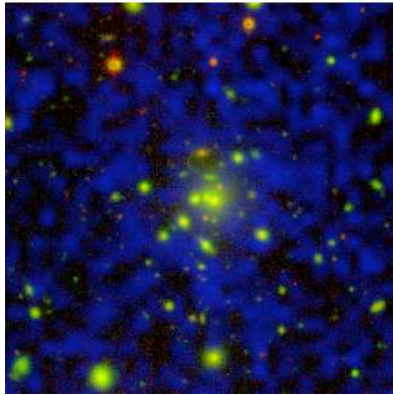
Redshift comparison



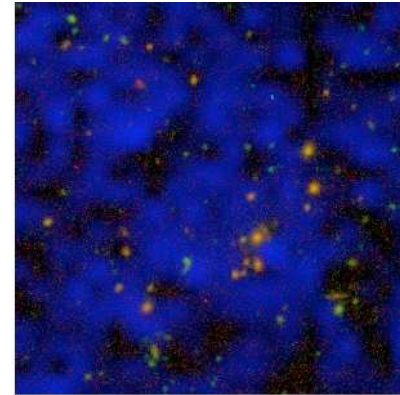
■ 193 free XCS cluster redshifts

# Redshift estimates

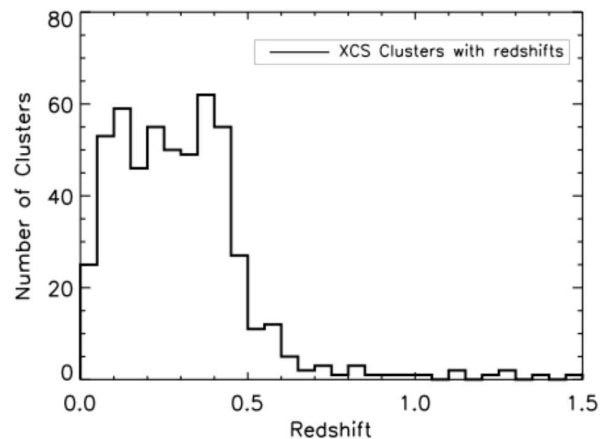
Dedicated XCS photometric follow up  $NOAO + XCS = NXS$



$z = 0.27 \pm 0.02$



$z = 0.53 \pm 0.01$



- More than 300 redshifts
- 136 for <sup>500</sup>XCS clusters

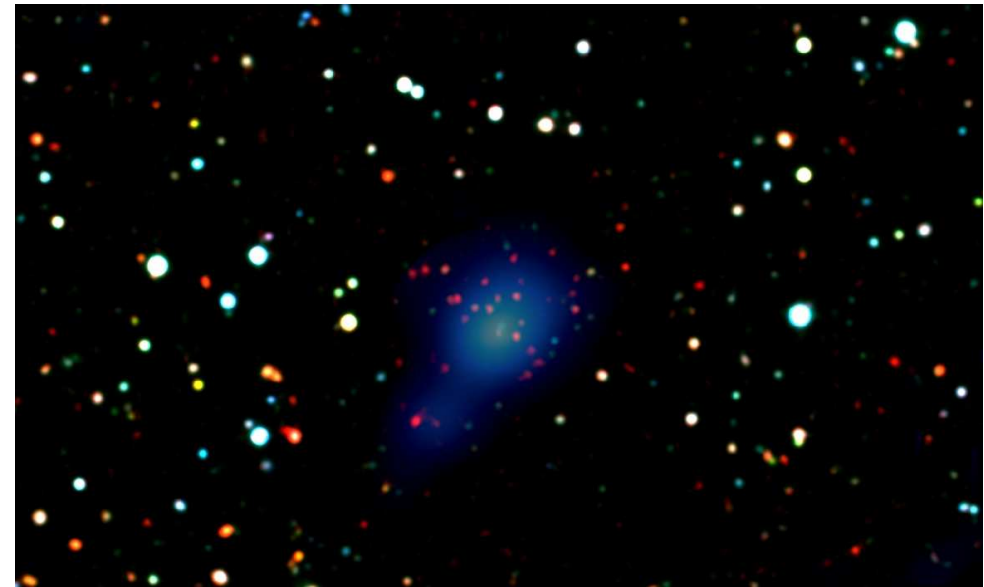
Merhtens et al, in prep



# High redshift cluster

The most distant spectroscopically confirmed cluster of galaxies found to date.  
XMM-XCS J2215.9-1738 or J2215. Stanford et al astro-ph/0606075, Hilton et al astro-ph/0708.3258

- 5 pointings of a  $z = 2.215$  quasar
- Total time  $273ks$
- $z = 1.45$
- $Temp > 6keV$



Original optical image

# High redshift cluster

The most distant spectroscopically confirmed cluster of galaxies found to date. XMM-XCS J2215.9-1738 or J2215. Stanford et al astro-ph/0606075, Hilton et al astro-ph/0708.3258

- 5 pointings of a  $z = 2.215$  quasar
- Total time  $273ks$
- $z = 1.45$
- Temp  $> 6keV$
- HST enhanced image
- $\sigma_v = 580 \pm 140 km s^{-1}$
- Expect to find  $\approx 10$  in sample



# Scaling relations

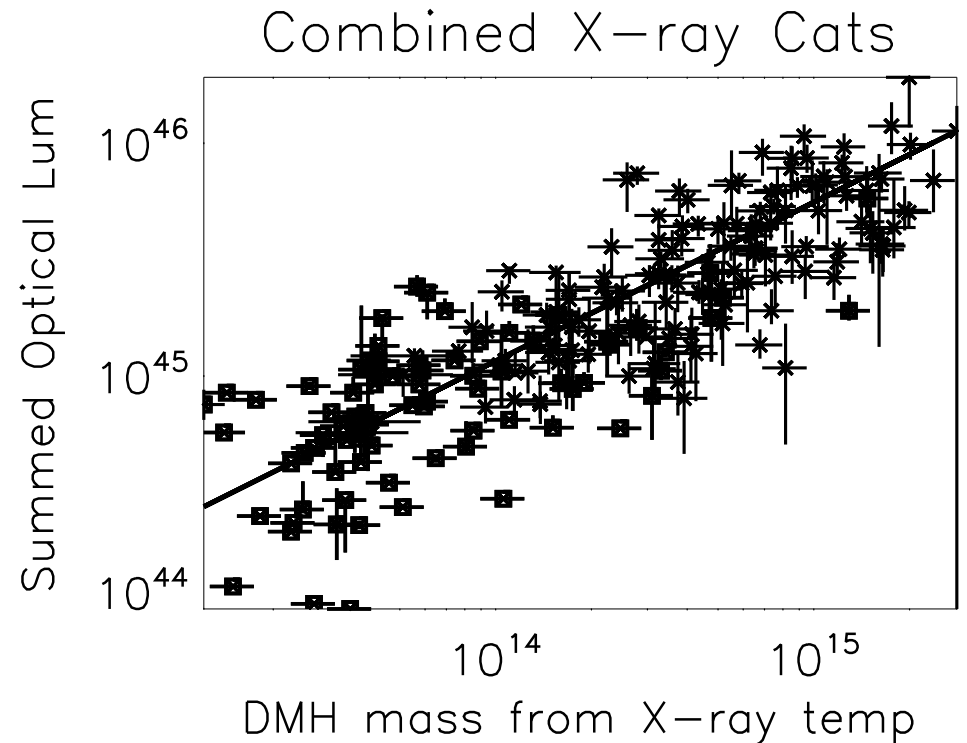
Combining optical [large numbers, no masses] and X-ray [small numbers, masses] cluster catalogues to obtain a mass proxy applicable to optically selected clusters.

## Xray

- eBCS, BCS, R400D, XCS
- reprocessed equally
- Tx -> Mass [Dai et al]

## Optical

- SDSS DR6
- $L_{opt} \propto T_X \propto Mass$
- Mass estimates to optical clusters
- Implications for DES, DUNE ...



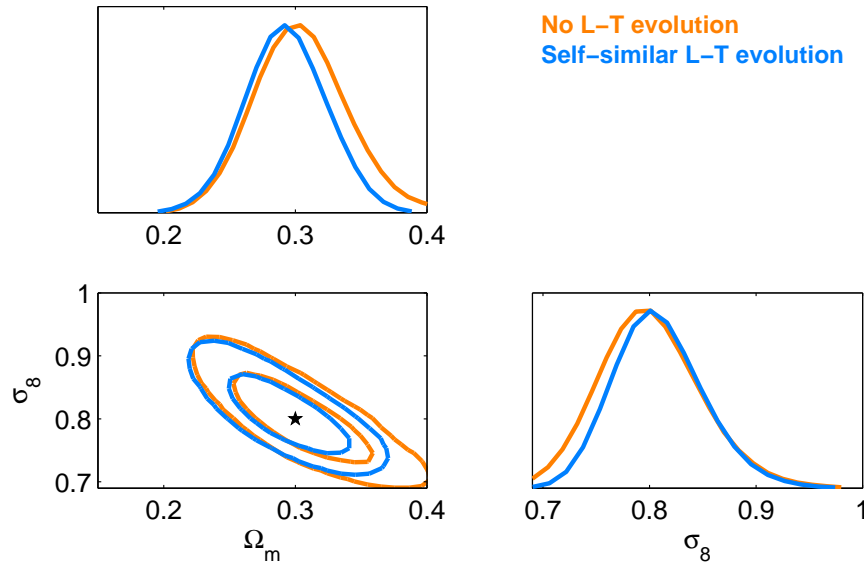
Empirical relationship:

$$L_{opt} = 10^{35+0.35}_{-0.35} (Mass)^{0.7+0.22}_{-0.21}$$

Hoyle et al, in prep

# Cosmology

Predicted realistic cosmological constraints from the final <sup>500</sup>XCS 500 sq. deg. using clusters with measured temperatures, and assuming photometric errors.



Expected Accuracy		
$\Omega_M$	= 0.3	$\pm 0.3$
$\sigma_8$	= 0.8	$\pm 0.05$
$L_X - T_X$	slope	13%
	normalisation	6%

Sahlén et al astro-ph/0802.4462