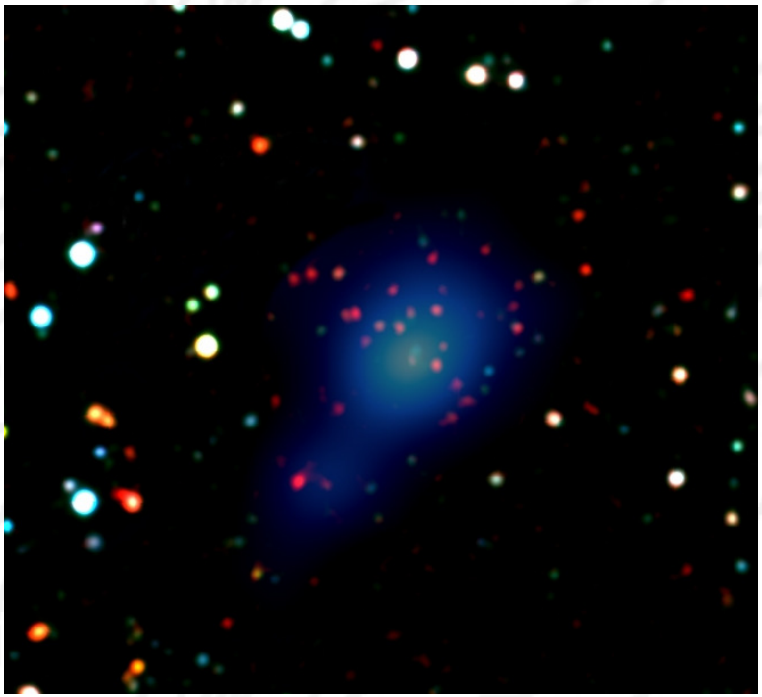
XCS

XMM Cluster Survey

liverpool JMU

Discovering the most distant galaxy clusters …



Matt Hilton

On behalf of the XCS collaboration:

Chris Collins, Michael Davidson, Mark Hosmer, Scott Kay, Andrew Liddle, Bob Mann, Nicola Mehrtens, Chris Miller, Bob Nichol, Kathy Romer (PI), Kivanc Sabirli, Adam Stanford, Pedro Viana, Mike West.

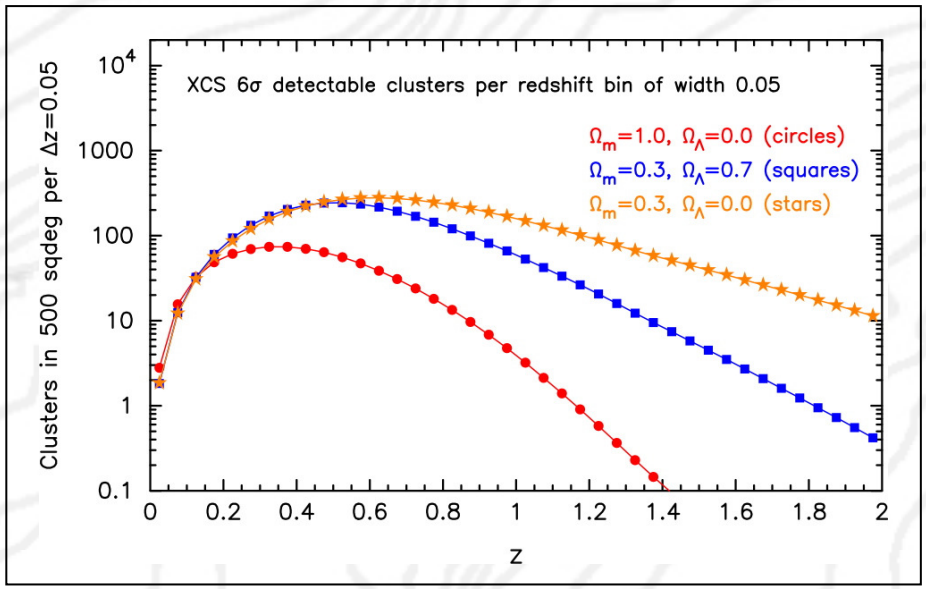
Outline

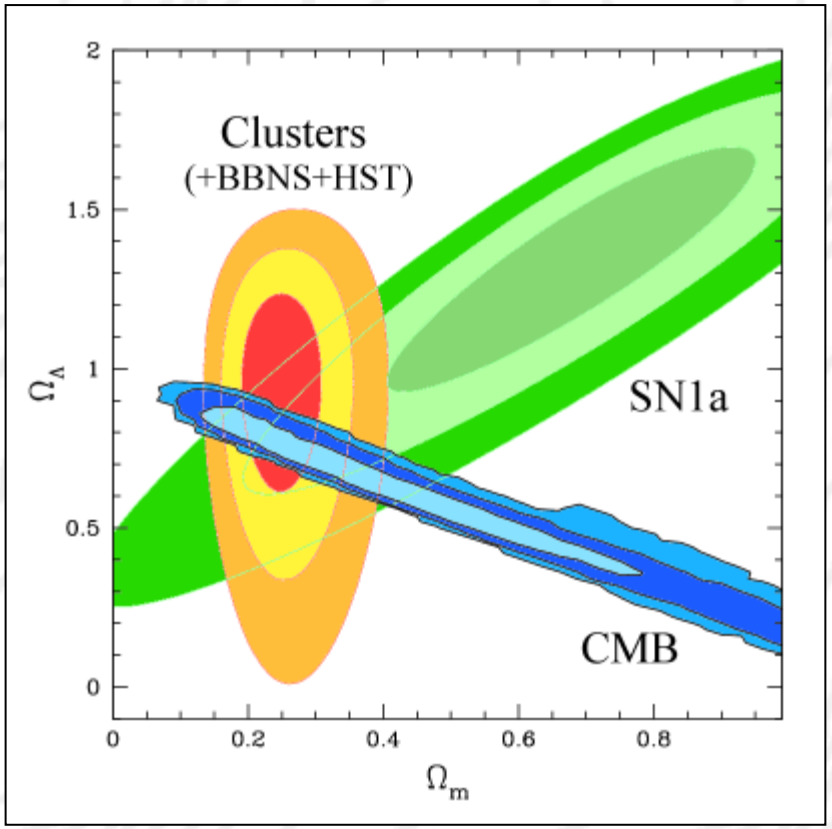
- What is XCS?
  - Science goals
- Detection methodology
- Current status
- A massive galaxy cluster at z=1.45
- The NOAO-XCS (NXS) follow-up survey
- Summary

What is XCS?

- The XMM Cluster Survey aims to mine the entire XMM science archive for galaxy clusters.
- The science goals of the XCS are:
  - To measure cosmological parameters σ_8, Ω_M, Ω_Λ to 5, 10 and 15 per cent accuracy respectively.
  - To study the evolution of the cluster gas (i.e., the luminosity—temperature relation) to high redshift.
  - To provide a statistically significant, homogeneously selected sample of high redshift clusters, in order to test theories of cluster galaxy formation and evolution.

XCS and Cosmology

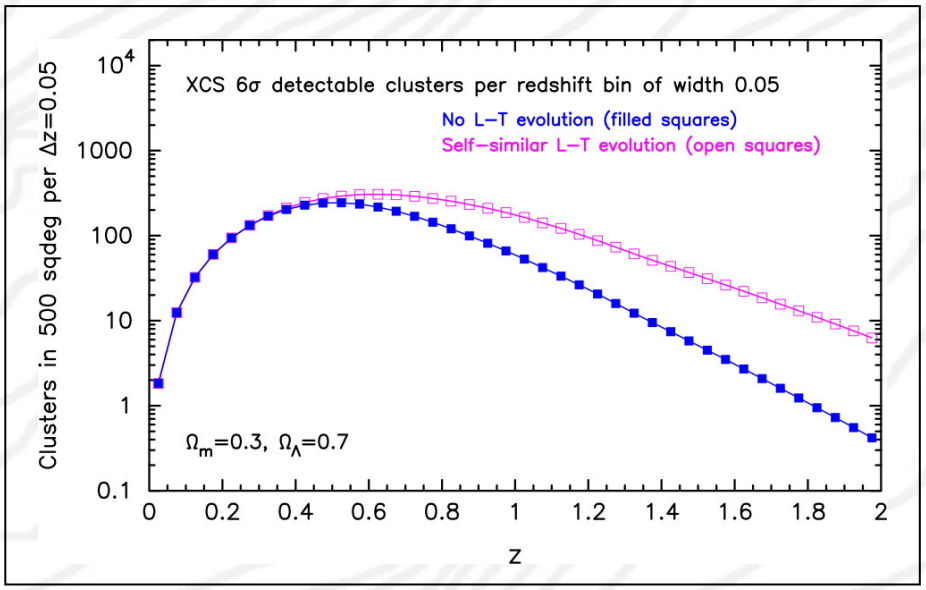


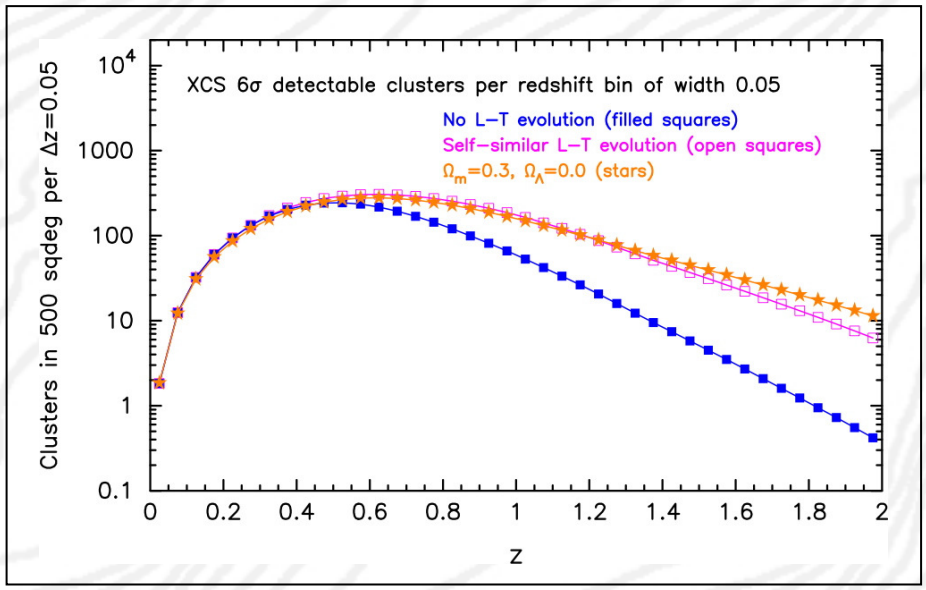


- The number density evolution of clusters with redshift provides constraints on cosmological parameters independent of those provided by SNIa searches or CMB experiments …

XCS and the L—T Relation

- … but only once the redshift evolution of the X-ray luminosity—temperature relation is understood.





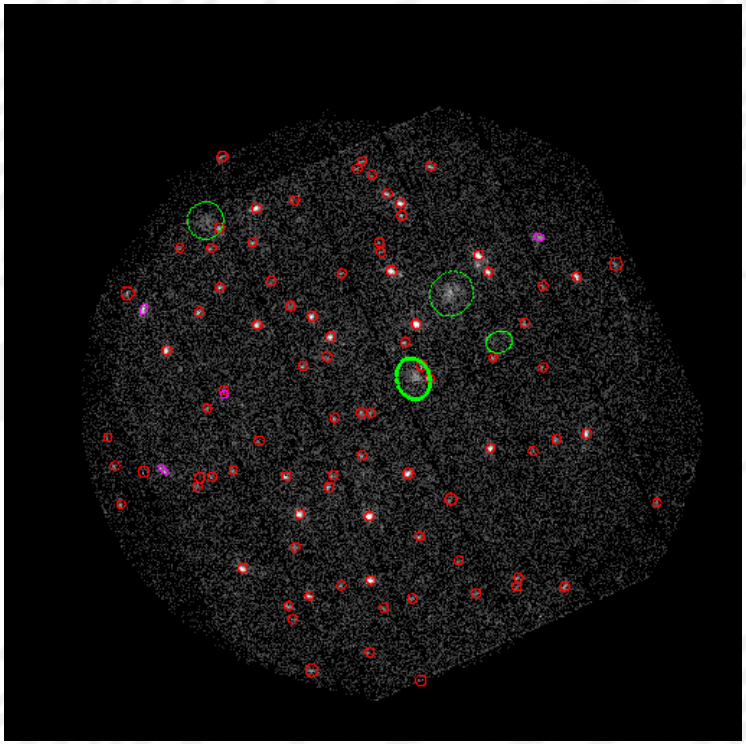
XCS and z>1 Clusters

- As well as providing the tightest constraints on cosmological parameters and the evolution of the L—T relation, the highest redshift clusters can also be used to constrain models of cluster galaxy formation and evolution – progress here is currently being hampered by a lack of examples at z>1.

Redshift	**Identification**	**Reference**
Z=1.45	*XMMXCS J2215.9*	*Stanford et al. 2006*
Z=1.41	ISCS J143809	Stanford et al. 2005
Z=1.393	*XMMU J2235.3*	*Mullis et al. 2005*
Z=1.273	*RDCS J0848.6*	*Stanford et al. 1997b*
Z=1.265	*RDCS J0848.9*	*Rosati et al. 1999*
Z=1.237	RDCS J1252.9	Rosati et al. 2004
Z=1.14	*RX J1053.7*	*Hashimoto et al. 2004*
Z=1.11	RDCS J0910	Stanford et al. 2002
Z=1.05	*XLSS J022403.9*	*Andreon et al. 2005*
Z=1.0	*XLSS J022708.7*	*Andreon et al. 2005*

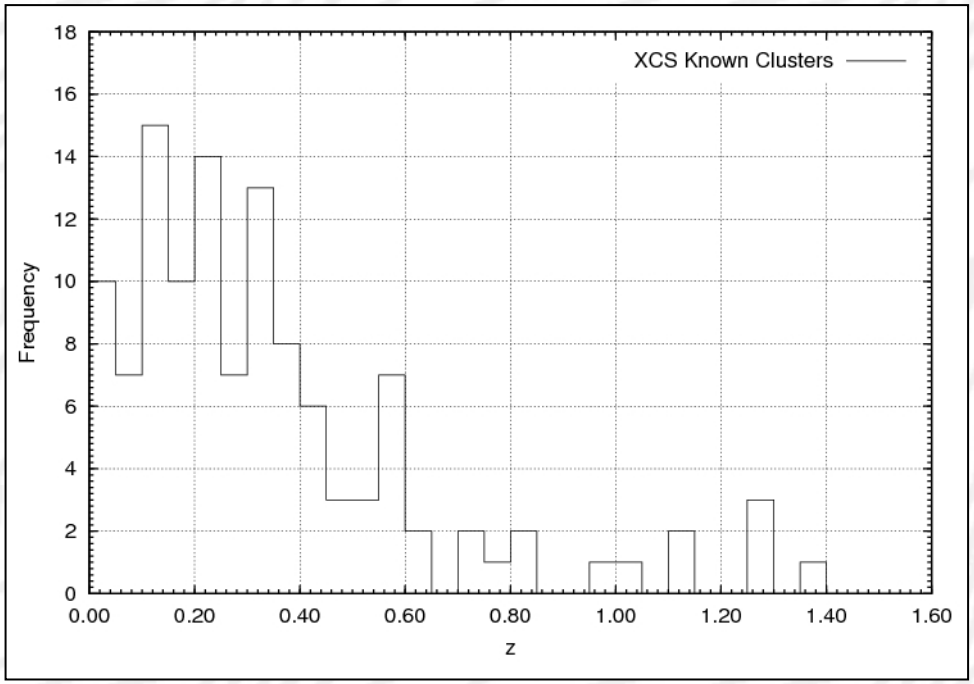
XCS Source Detection

- The XCS analysis pipeline uses a custom wavelet-based detection algorithm (based on wavdetect by Peter Freeman).
- One of the main advantages of this approach is that point sources within extended sources can be identified and excised.



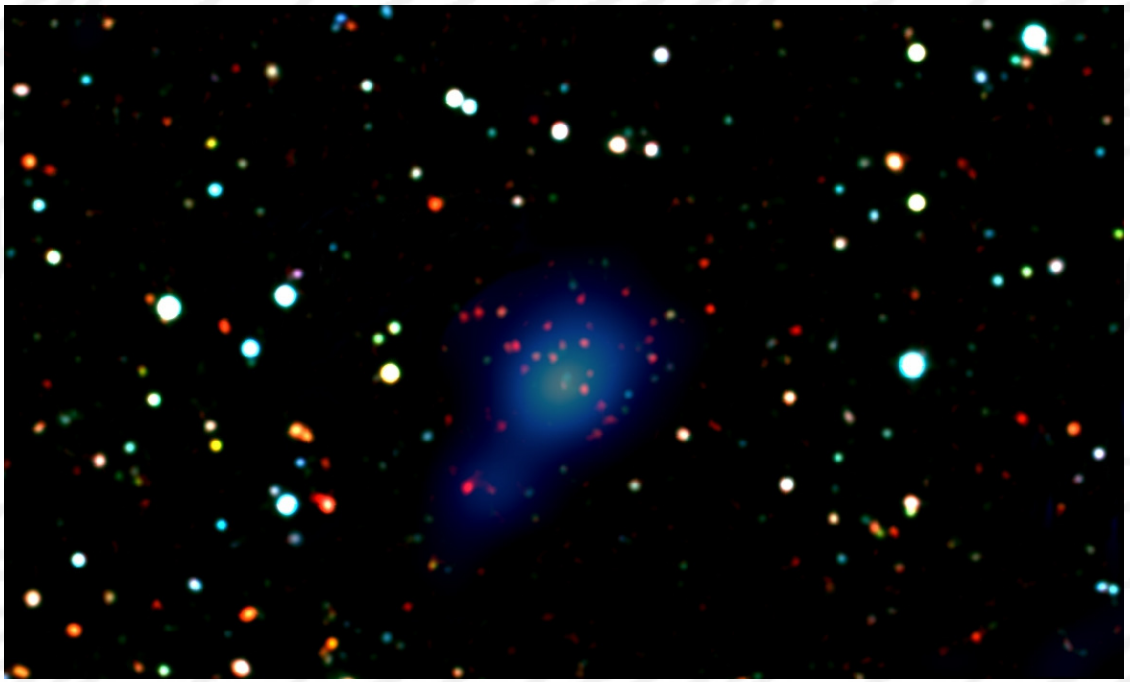
XCS: Current Status

- We will make the first XCS data release this autumn, based on processing of 1,849 XMM pointings covering 168 deg^2 at |b|>20°.
- This initial catalogue contains 1,764 cluster candidates:
  - 1622 new cluster candidates.
  - 142 known clusters (from NED/SIMBAD).
  - 7 of these known clusters are at z>1.



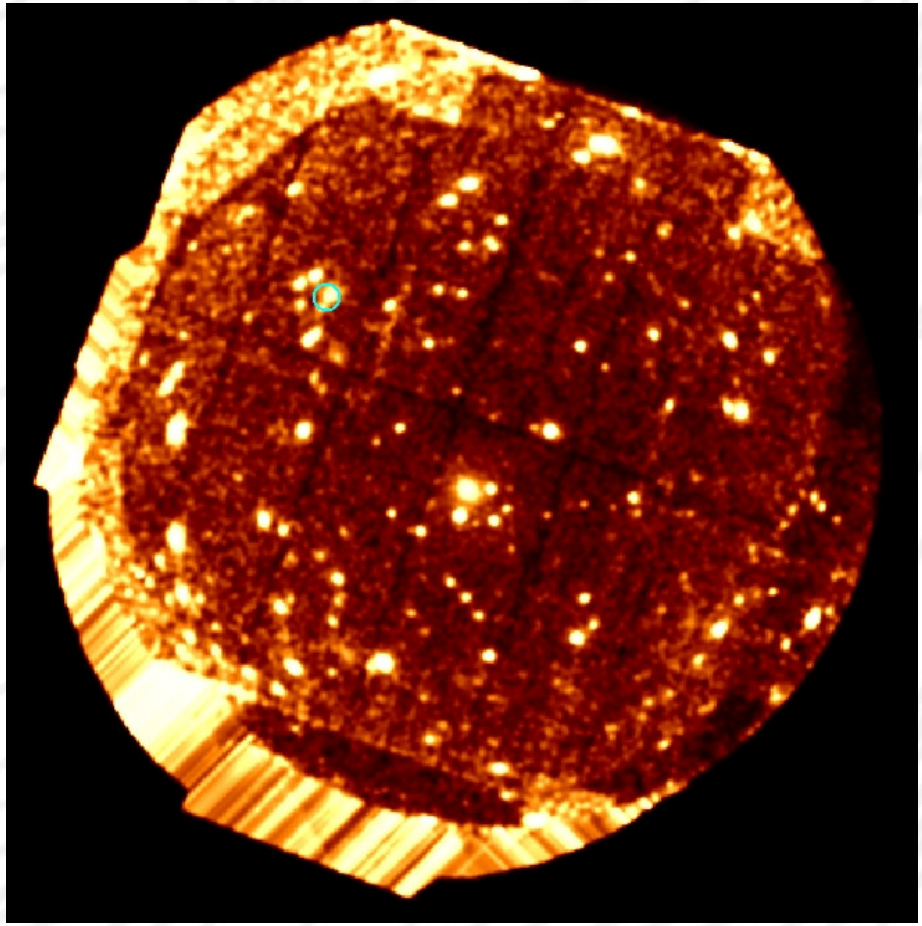
XMMXCS J2215.9-1738

- We have recently discovered the most distant known galaxy cluster to date – XMMXCS J2215.9-1738 at z=1.45 (Stanford et al. 2006, in press, astro-ph/0606075).

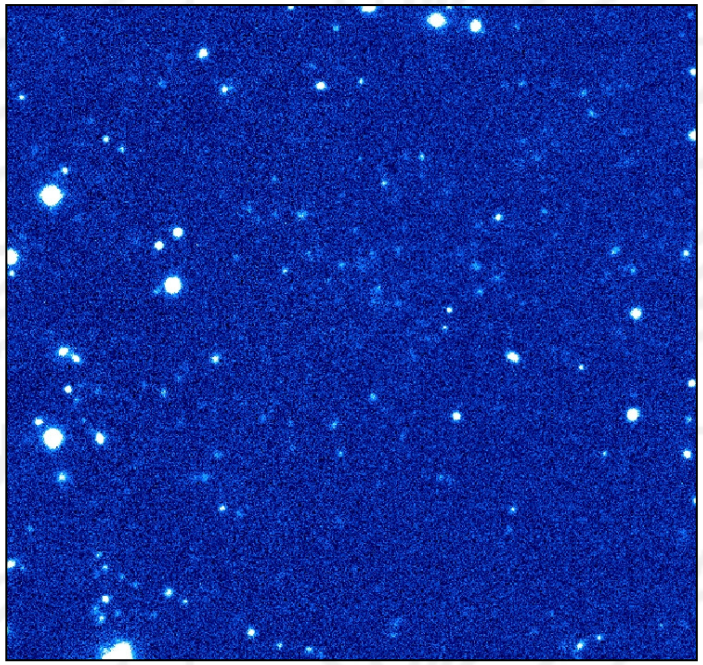


X-ray Observations

- XMMXCS J2215.9-1738 was detected as an extended X-ray source in XMM observations of the quasar LBQS 2212-1759 (z=2.217).
- The source was detected at an off axis angle of 9′, and the total exposure time (MOS1) is 237 ks.



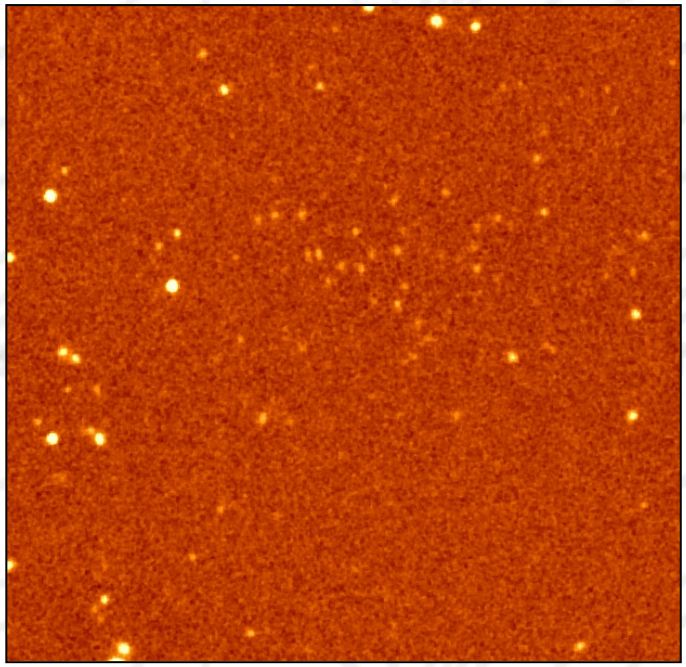
Optical Observations



- The ESO Imaging Survey of XMM fields (EIS-XMM; Dietrich et al. 2005) provides coverage of this pointing – inspection of the 9000-sec I-band image (taken with WFI on the MPI 2.2m telescope) revealed a collection of I~23-24 galaxies.

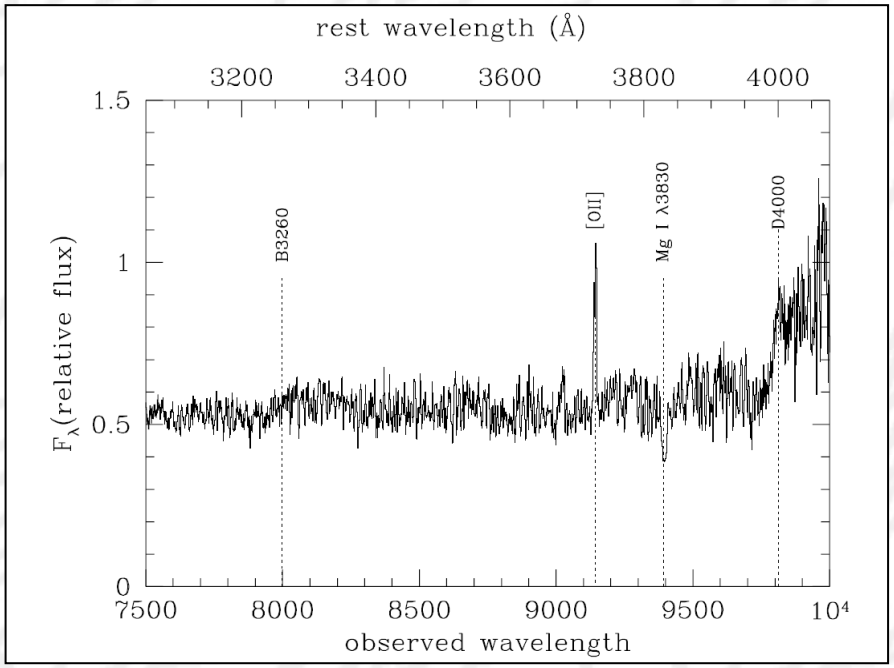
- On this basis, the object was selected for follow-up with DEIMOS on Keck II.

Optical Observations

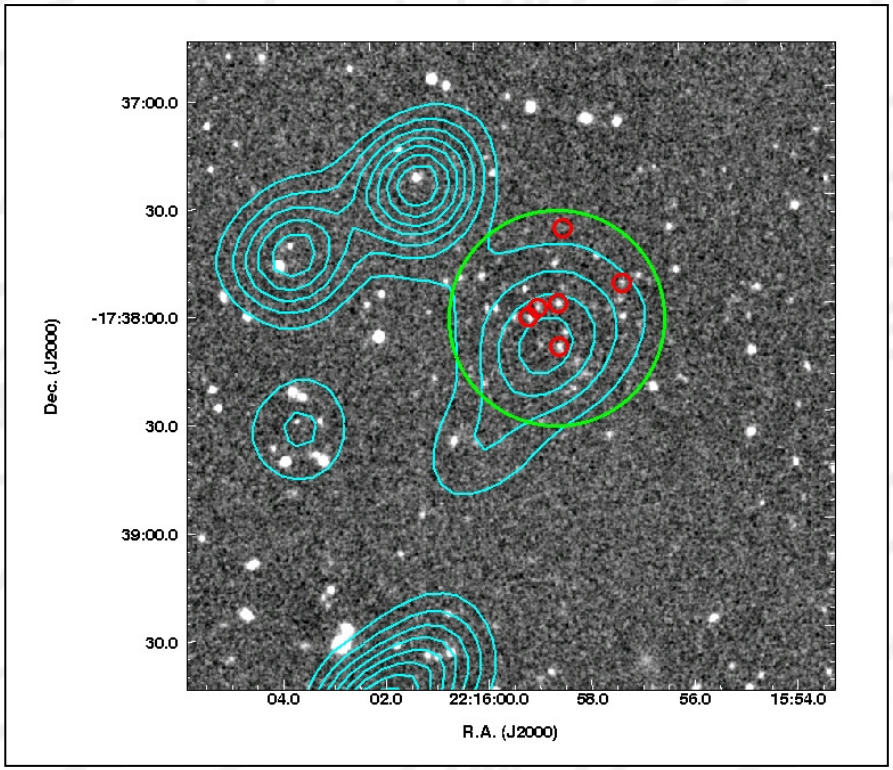


- Six galaxies were found with concordant redshifts at z=1.45 within 30” of the X-ray centroid.

- Subsequent to the first Keck run, a K-band image of the cluster was obtained courtesy of Chris Conselice. A second slit mask was prepared, with target galaxies selected using the I-K colour.

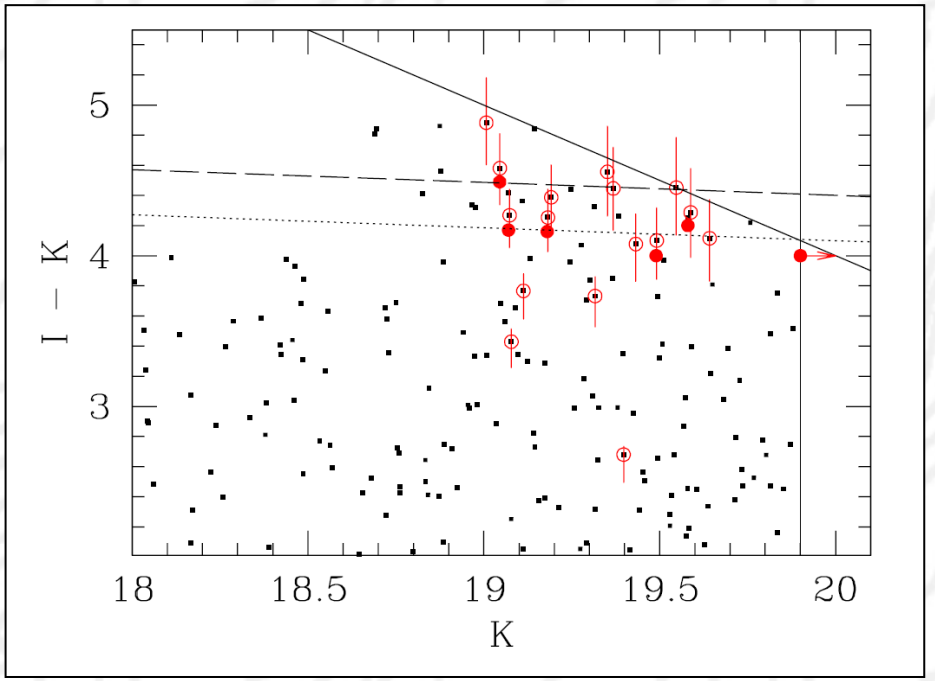


Optical Observations



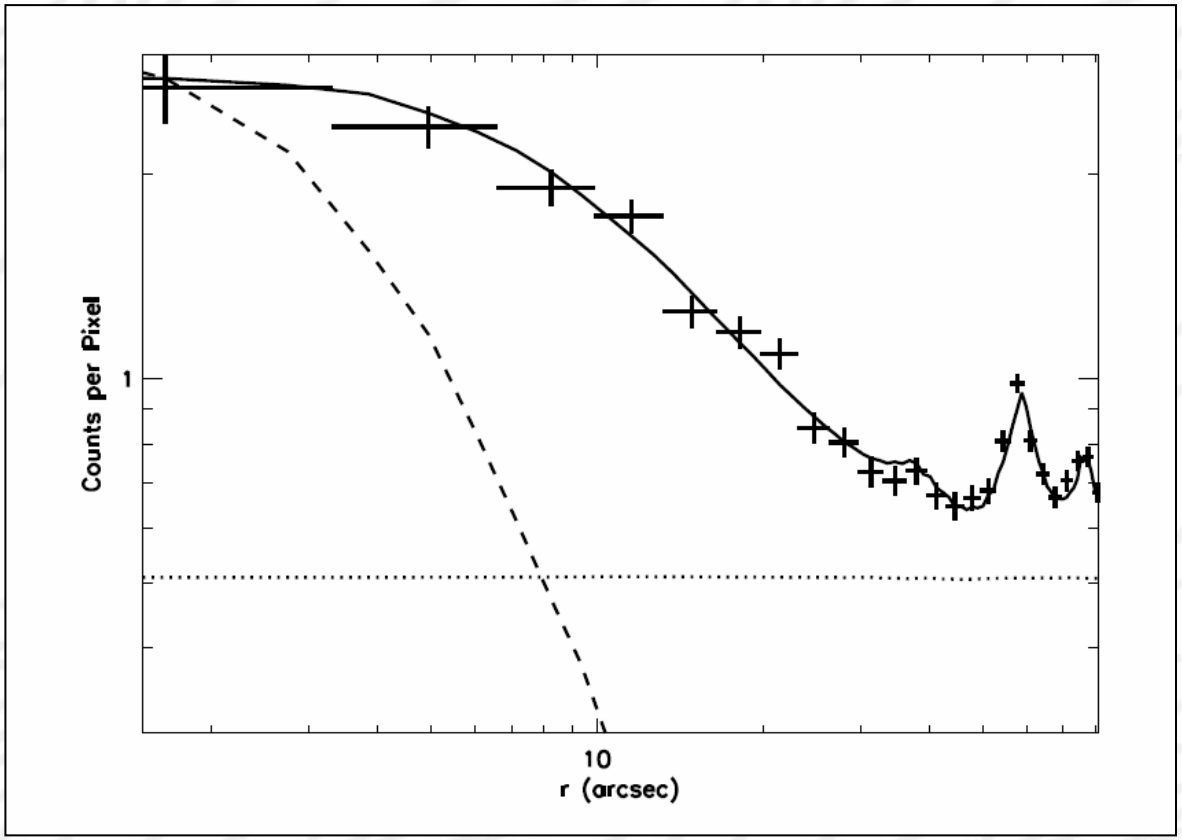
Above: Red circles mark spectroscopically confirmed members. Green circle marks the 30″ aperture used in X-ray analysis.

Below: Solid lines mark the limits of the I and K photometry. Filled red circles are spectroscopic members. Dashed line – model red-sequence for z_f=3.0. Dotted – z_f=2.0



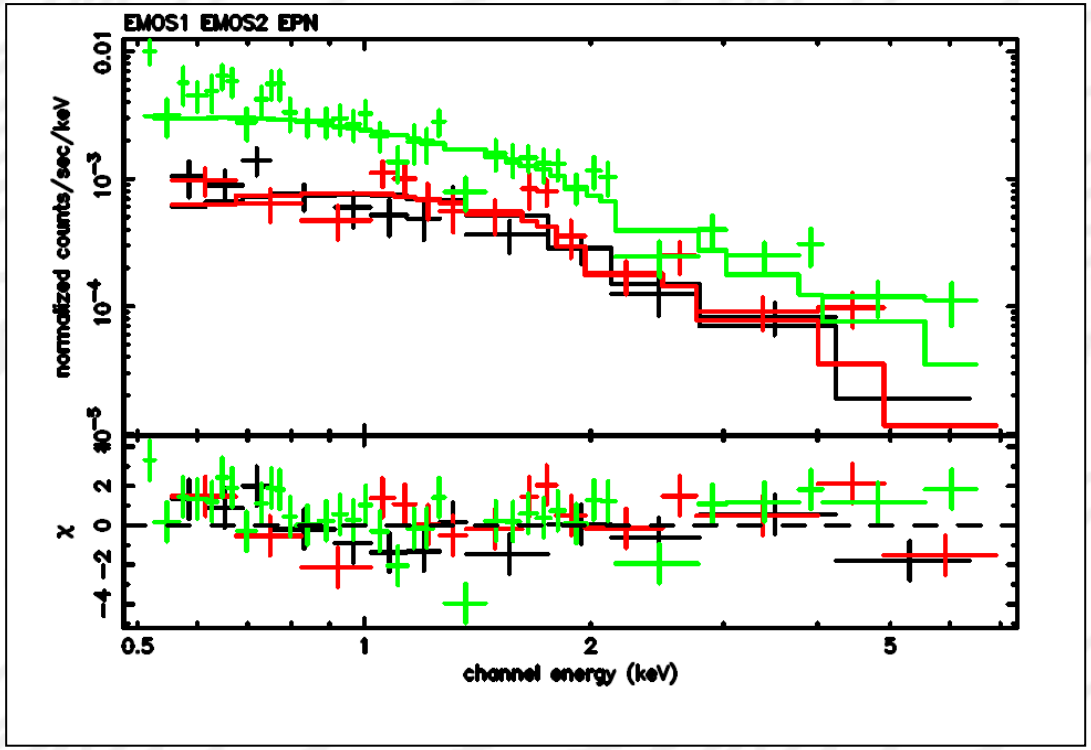
X-ray Analysis

- What about the point sources?
  - The spatial profile of the X-ray emission:



X-ray Properties

- The X-ray spectrum (EMOS1 EMOS2 EPN):



Flux [0.5-2.0 keV]: $1.22^{+0.21}_{-0.17} \times 10^{-14}$ erg s^{-1} cm^{-2}

Luminosity [0.5-2.0 keV]: $1.15^{+0.20}_{-0.16} \times 10^{44}$ erg s^{-1}

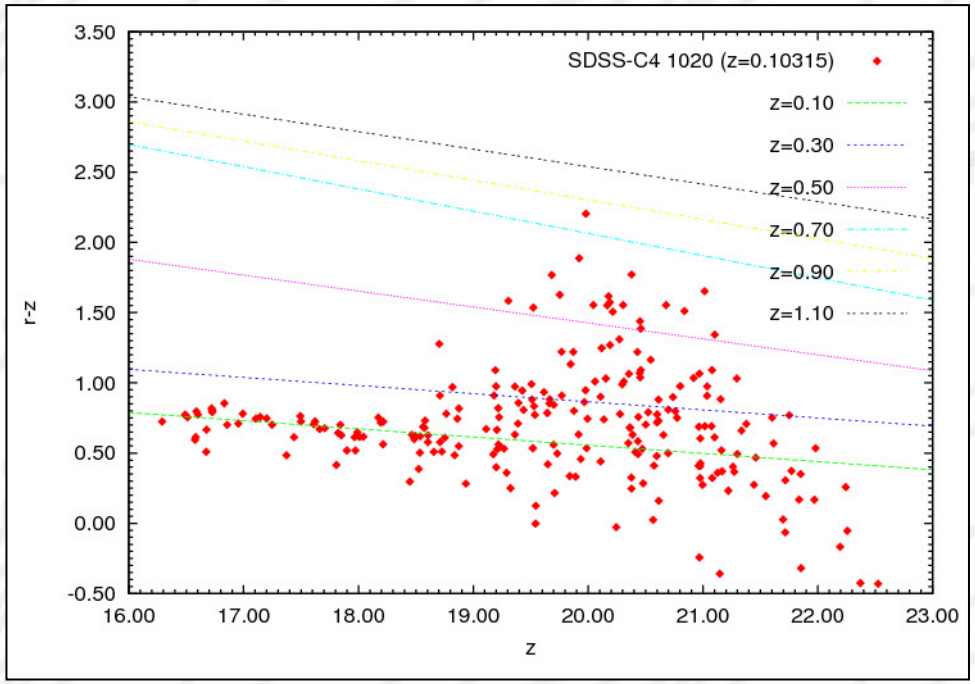
Temperature: $7.4^{+2.7}_{-1.8}$ keV ($6.5^{+2.6}_{-1.8}$ keV)

The NXS Follow-up Programme

- The NOAO-XCS (NXS) is a NOAO Survey programme which will observe ~330 XMM pointings over the next three years, using the MOSAIC-1 and 2 optical CCD imaging cameras on the KPNO and CTIO 4m telescopes.
- The NXS will obtain photometric redshift estimates for XCS clusters by exploiting the fact that the early-type galaxies that make up the bulk of the cluster galaxy population form a conspicuous Colour Magnitude Relation (CMR), up to z~1.3 (e.g. Blakeslee et al. 2003; Toft et al. 2004).
- The use of the CMR for cluster redshift estimation was first suggested and applied by Gladders & Yee (2000, 2005) in the Red-sequence Cluster Survey.

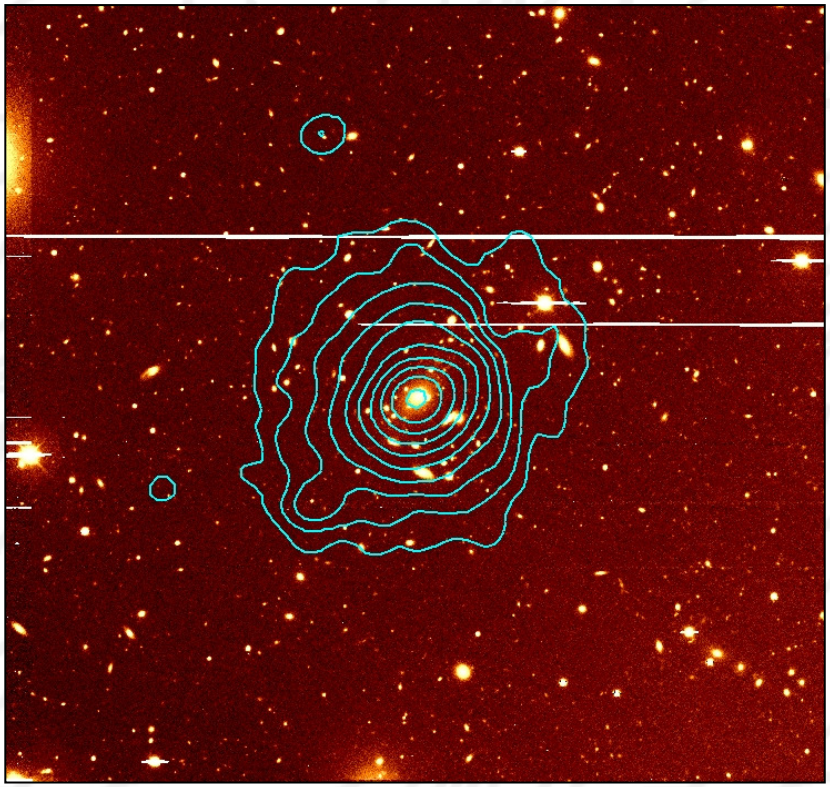
The NXS Follow-up Programme

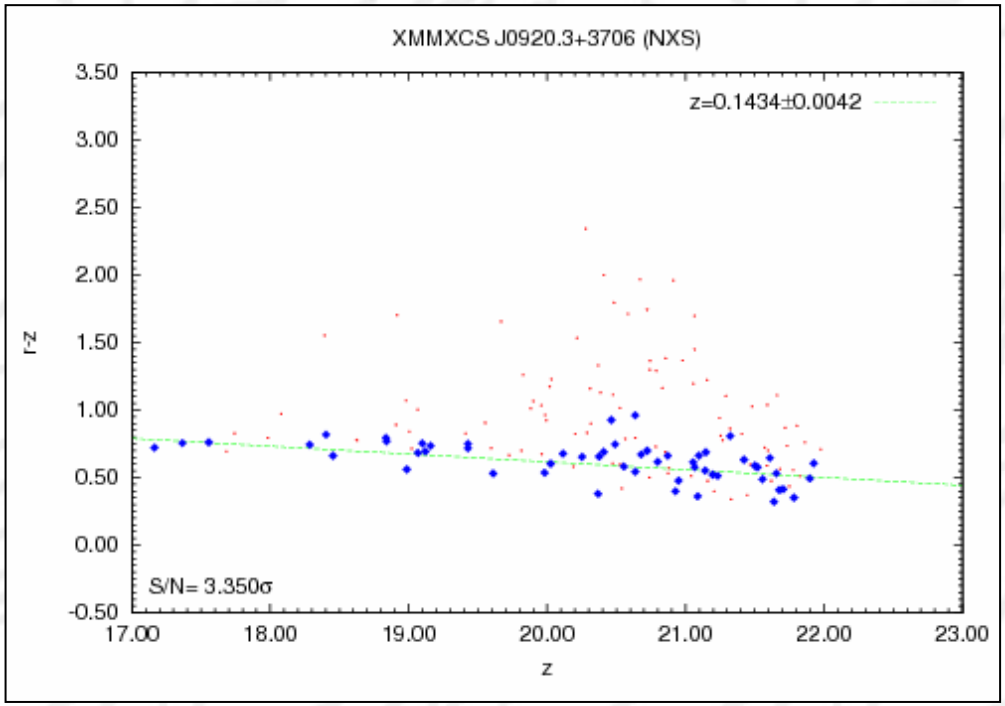
- The filters chosen for NXS are SDSS r′ and z′, allowing us to estimate cluster redshifts up to z~1.1.



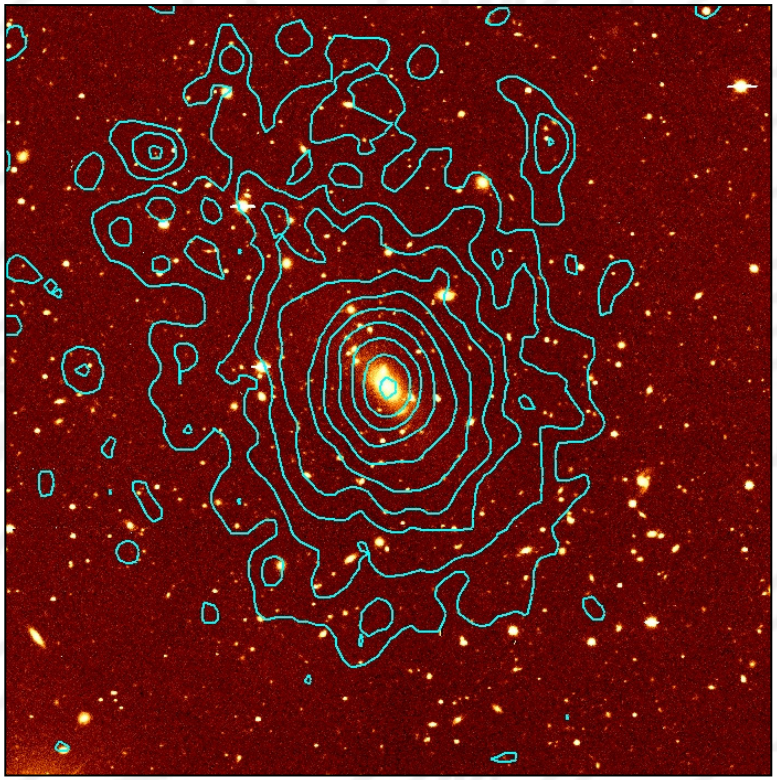
- The first NXS observing run took place at KPNO in November 2005 …

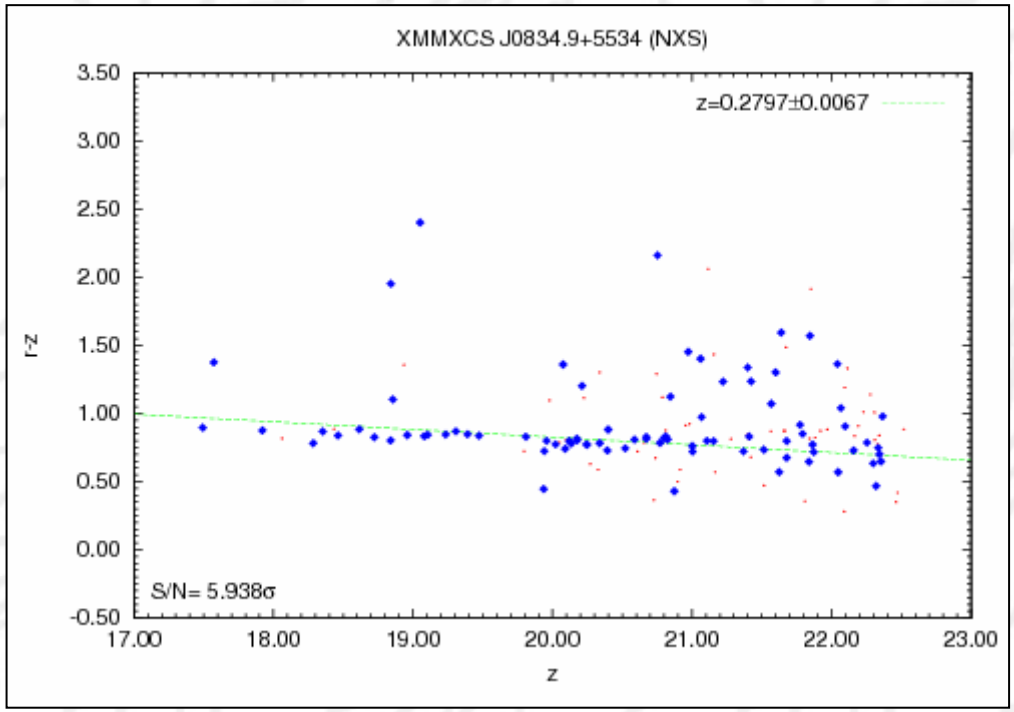
XMMXCS J0920.3+3706



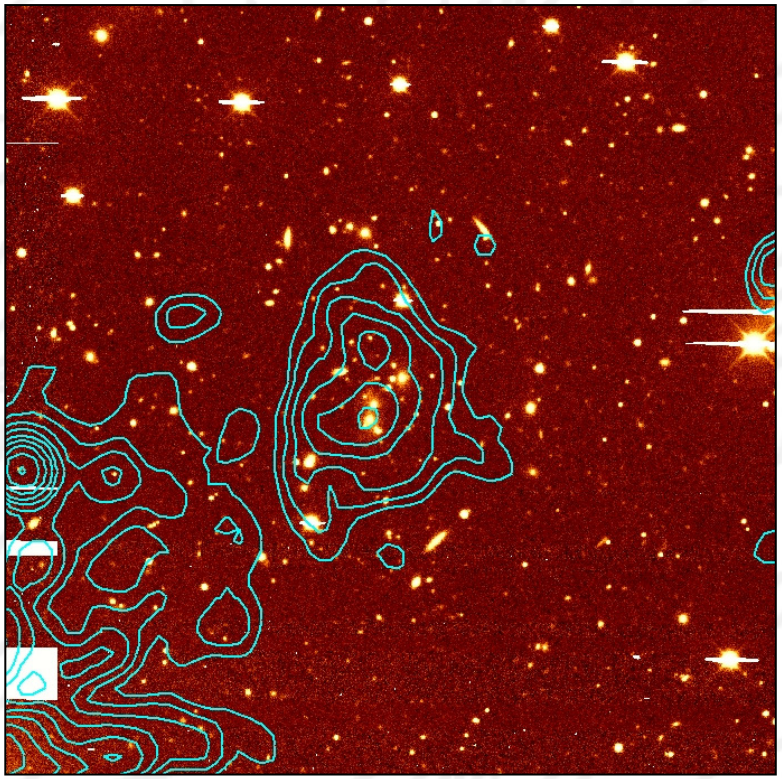


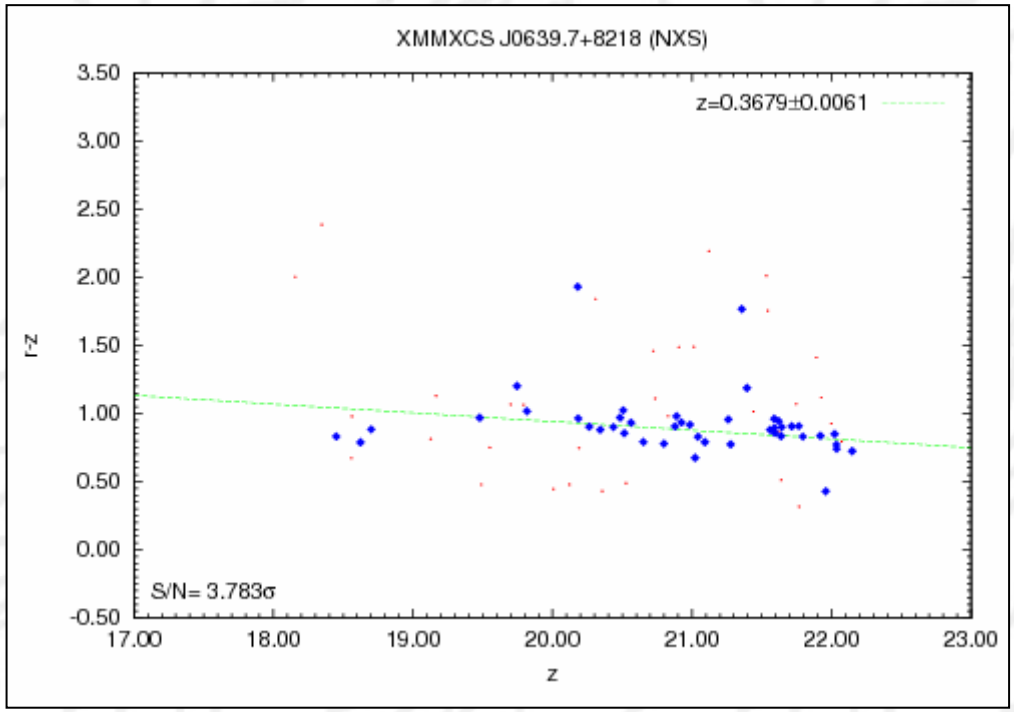
XMMXCS J0834.9+5334



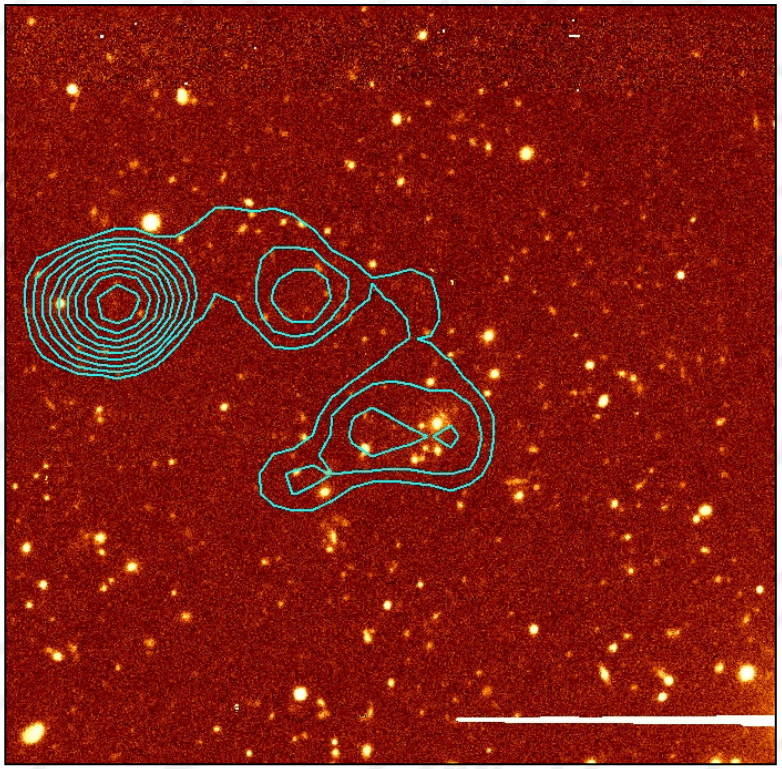


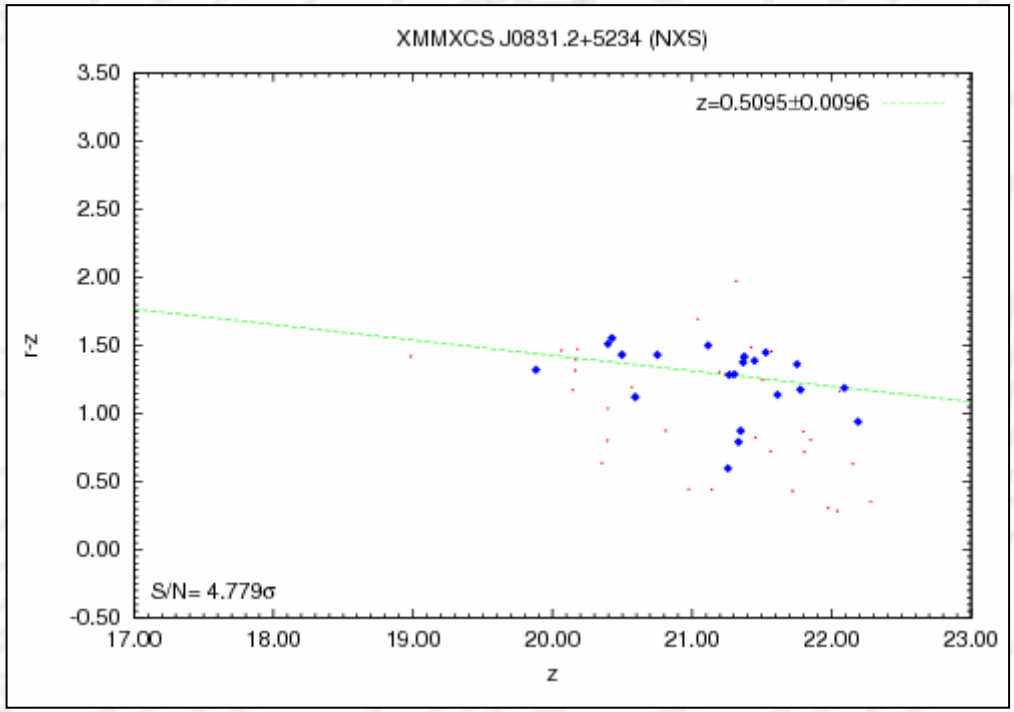
XMMXCS J0639.7+8218





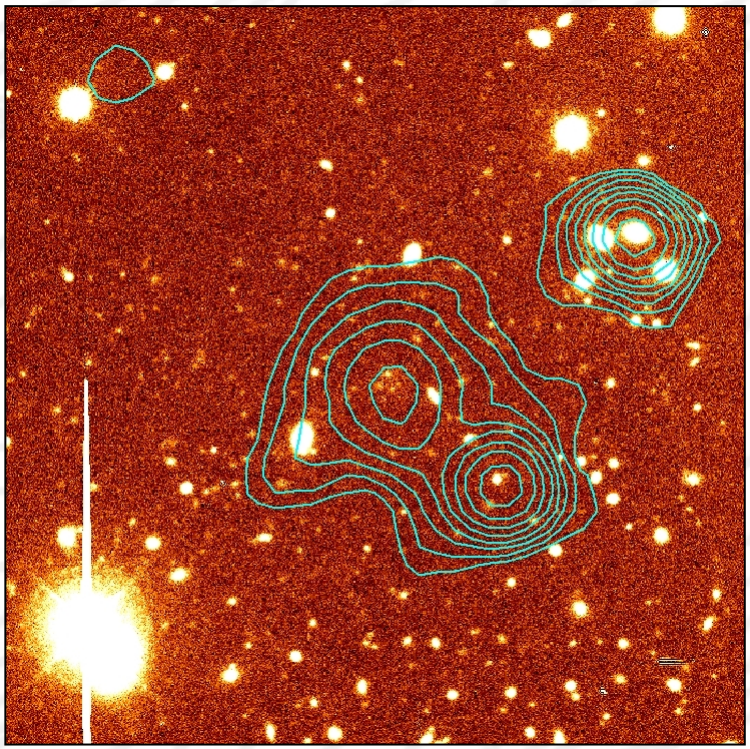
XMMXCS J0831.2+5234

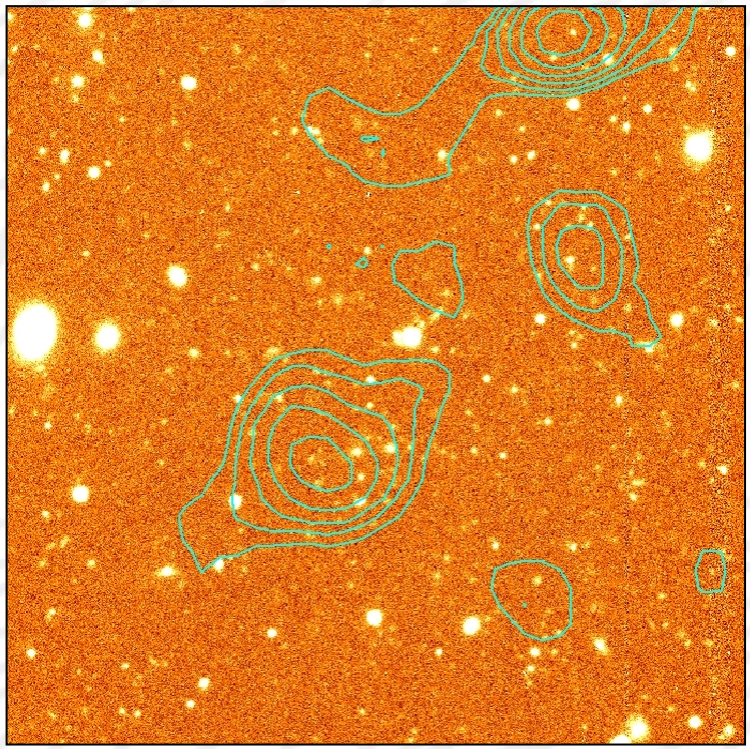




More Spectroscopic Follow-up

- Distant cluster candidates identified in the NXS first run data will be followed-up spectroscopically in 2006B by Gemini and Keck.
- Gemini targets:





Summary

- The XCS aims to:
  - measure cosmological parameters.
  - study the evolution of the cluster gas to high-redshift (L—T relation).
  - construct a statistically significant, homogeneously selected catalogue of z>1 galaxy clusters that can be used to test theories of cluster galaxy formation and evolution.
- We have recently discovered the most distant galaxy cluster found to date, XMMXCS J2215.9-1738 at z=1.45.
- The NXS optical follow-up campaign is underway. Using the first run data we have:
  - implemented a cluster red-sequence based redshift estimator.
  - identified some high-redshift cluster candidates in these data for spectroscopic follow-up with Keck and Gemini in 2006B.