A Large X-Ray Sample of Fossil Groups

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MOTIVATION

Fossil groups are systems dominated by a single, giant elliptical galaxy, yet their X-ray emission indicates a much deeper, cluster-scale gravitational potential. They are thought to be old, undisturbed galaxy groups in which the large galaxies have merged via dynamical friction. However, there are indications (lack of cool cores, star formation enrichment) that these systems may be younger or more active than previously thought. These results are complicated by the small number of fossil groups with deep X-ray data.

To address this, we have constructed a sample of 15 fossil groups from the maxBCG optical cluster survey. Here we present *Chandra* snapshot observations of this first large, X-ray sample of optically identified fossil groups. We also describe plans for a deep *XMM* follow-up program that will measure density, temperature, and abundance profiles, and constrain the formation mechanism of these peculiar but numerous systems.

SAMPLE SELECTION

The 15 candidate FGs were selected from the maxBCG cluster survey (Koester et al. 2007) using the following criteria:

- $0.09 < z < 0.15$
- $L_{BCG} > 9 \times 10^{11}\ L_{\odot}$
- $\Delta i > 2.0$ between BCG and second-ranked galaxy within $R_{200}/2$
- no optical/radio AGN

Some of the selection criteria are illustrated in Figure 1. Of the 15 candidates, 6 have > 2-σ detections from the ROSAT All-Sky Survey. The L_X for the other targets were estimated using a ROSAT stacking analysis of 170 similar maxBCG clusters (Rykoff et al. 2008). These RASS sources are extended and not simply points sources, as a comparison to the ROSAT PSF shows (see Figure 2).

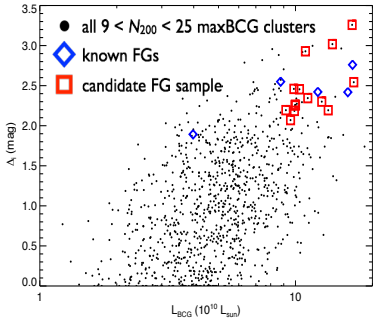

Figure 1. Sample selection from maxBCG catalog.

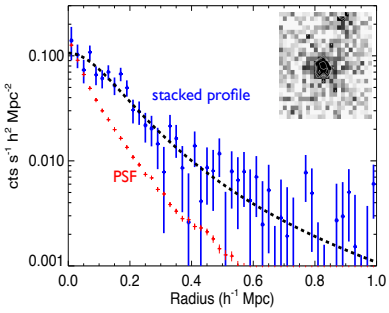

Figure 2. Stacked RASS profile compared to PSF.

OBSERVATIONS & DATA REDUCTION

Fourteen of the 15 targets in our sample have been observed with *Chandra* ACIS-S3 starting in Dec 2008. The snapshot exposures of 5-10 ksec are summarized in Table 1.

Spectra were extracted from a circular region 250 kpc in radius at the redshift of each group. Point sources were identified using *wavdetect* and excluded from the extraction. Spectral fits were performed in XSPEC, using an absorbed APEC model with the abundance fixed at 0.3 solar. The best-fit T_X and unabsorbed soft L_X (0.5-2 keV in the source frame) are also given in Table 1. Smoothed X-ray images for each FG candidate are displayed in Figure 3, overlayed on SDSS *g,r,i* composite images.

Of the 14 targets, 11 have extended emission detected at greater than 90% confidence, with 9 of these (at greater than 3-σ) allowing reliable temperature determination.

FG	z	ksec	cts	L42	kT	
SDSS J0856	0.09	5	283	4.6	2.1	
SDSS J0907	0.11	5	366	10.1	2.7	
SDSS J1017	0.12	10	121	1.8	2.0	
SDSS J1045	0.15	10	521	13.0	2.8	
SDSS J1133	0.13	6	165	4.7	1.9	✔
SDSS J1136	0.10	5	218	4.9	3.0	
SDSS J1153	0.12	5	157	4.6	1.9	
SDSS J1410	0.09	5	330	5.5	1.6	
SDSS J1411	0.11	7	147	2.5	1.5	
SDSS J0815	0.13	5	81	3.4	1.3	?
SDSS J1039	0.09	5	61	0.7	1.0	
SDSS J0133	0.11	10	104	< 1.7	...	
SDSS J0821	0.12	10	49	< 1.8	...	X
SDSS J0906	0.14	10	25	< 1.9	...	

FGs with > 2-σ RASS detections

Table 1. Summary of observations and results.

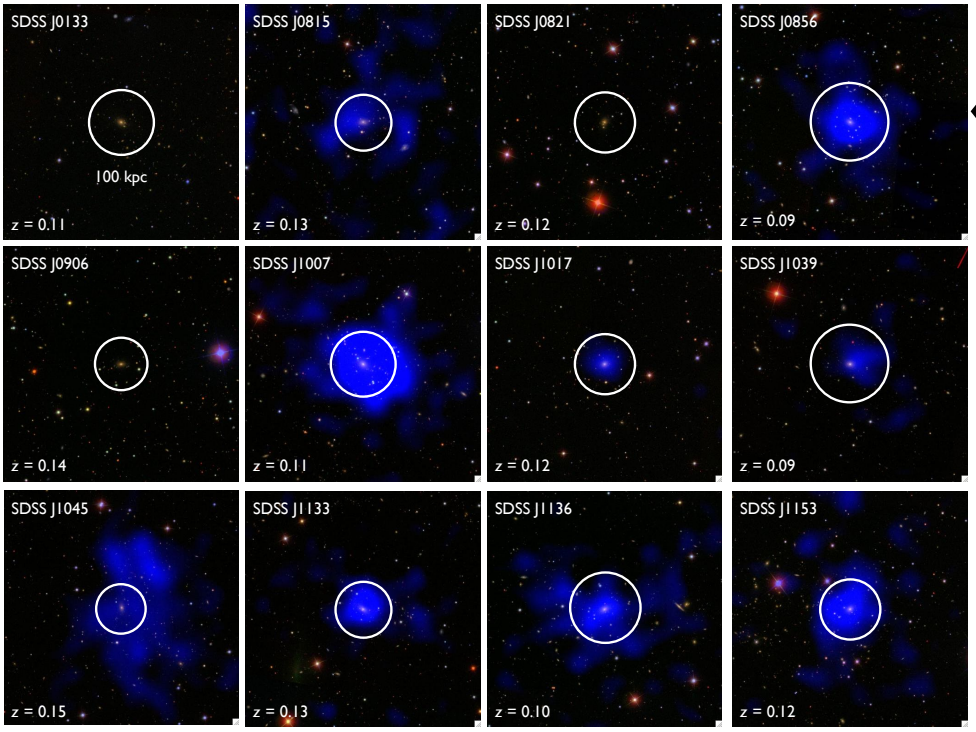

Figure 3. SDSS *g,r,i* composite images centered on the target BCG, with *Chandra* ACIS-S3 images overlaid in blue. The X-ray images have had point sources removed, have been exposure-corrected, and have been smoothed by a 30 arcsec FWHM Gaussian kernel. The image stretch is such that some noise features are seen in the snapshot X-ray images. White circles indicate 100 kpc radius at the FG redshift. The images are 6 arcmin on a side.

RESULTS

The L_X-T_X relation for our 9 good detections is shown in Figure 4, along with low-z groups and clusters and a sample of intermediate-z groups. The FG luminosities have been multiplied by an aperture correction of 1.5 to scale to r_{500}, and by a spectral-model-dependent bolometric correction ranging from 2.0-2.5. The aperture correction assumes the same beta model density profile for each FG, and we expect a systematic error from both scaling factors of ~ 50% in luminosity. The FG points (in red) lie close to the group-cluster L_X-T_X relation, in the region occupied by rich groups and poor clusters. There is a hint of a trend to lower L_X or hotter kT, although it is smaller than the systematic error. Detailed spatial analysis, currently underway, will allow us to more accurately estimate the proper aperture correction

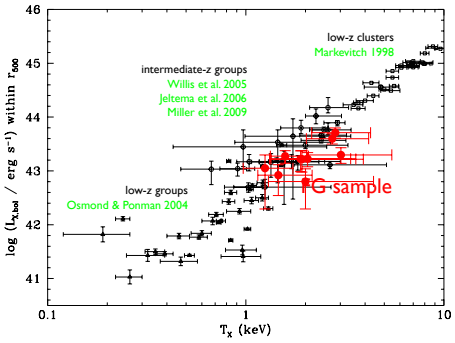

Figure 4. L_X-T_X relation, with our 9 well-detected candidate FGs shown in red.

THE NEXT STEP

With this sample of detected FGs, we intend to follow up with very deep *XMM* observations. Exposures with 10,000+ counts will enable us to very accurately measure temperature and surface brightness profiles. More interestingly, we will measure the dark matter concentration parameter, which will constrain the epoch of formation of these systems. We will also measure abundance profiles, which will indicate the importance of SN Ia and II enrichment processes as a function of radius, and identify recent activity in these fossil groups.