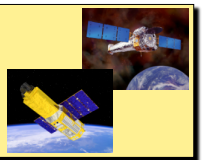
Intermediate-Redshift Groups in the XBootes Survey

Eric D. Miller, Mark Bautz, Catherine Grant (MIT)

William Forman, Christine Jones, Stephen Murray, Alexey Vikhlinin (SAO)

MIT Kavli Institute for Astrophysics and Space Research



MOTIVATION

Galaxy groups are key tracers of galaxy evolution, cluster evolution, and structure formation, yet they are difficult to study at even moderate redshift. We have undertaken a project to observe a flux-limited sample of intermediate-redshift ($0.1 < z < 0.5$) group candidates identified by the XBootes Chandra survey (Kenter et al. 2005). By exploiting the unique multi-wavelength coverage of the XBootes/NOAO Deep Wide Field Survey (NDWFS) field, we aim to:

(1) understand the physical connection between the X-ray and optical properties of groups
(2) constrain non-gravitational physics that alters the energetics of the intragroup medium

Of the 43 extended X-ray sources identified by the XBootes survey, 27 exceed our flux threshold of 2×10^{-14} erg s^{-1} cm^{-2}. This brightest 14 targets of this sample are listed in Table 1. Here we present deep *Suzaku*/XIS and *Chandra*/ACIS follow-up observations of the first five targets in this project.

TABLE 1
XBOOTES GROUP OBSERVATIONS

Group	z	$S14$	Telescope	Date Obs.	ksec	
1	0.151	4.2	Suzaku	Dec 2007	42	this work
7	0.194	4.7	Suzaku	June 2007	42	
30	0.222	4.1	Suzaku	June 2007	39	
2	0.234	6.9	Chandra	May 2007	38	
26	0.342	4.5	Suzaku	June 2007	44	
24	0.131	9.7	Chandra	GTO9	25	awarded
10	0.280	3.3	Chandra	GTO9	45	
37	0.215	2.3	Suzaku	AO3	40	
32	0.420	2.7	Suzaku	AO3	40	
23	0.130	22.1	Chandra	GO10		proposed
39	0.278	11.2	Chandra	GO10		
33	0.242	6.3	Chandra	GTO10		
14	0.350	4.2	Chandra	GTO10		

z: spectroscopic redshift from AGES survey
$S14$: 0.5-7 keV flux in units of 10^{-14} erg s^{-1} cm^{-2}, estimated from 5 ksec XBootes survey

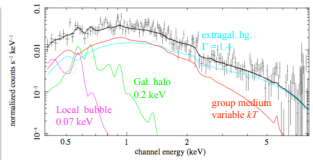


Figure 1. Emission model for *Suzaku*/XIS spectra, including X-ray background and group components.

TABLE 2
GROUP EMISSION PARAMETERS

Group	kT (keV)	abund.	S_X	L_X
1	0.7 ± 0.3	0.1 ± 0.1	5.6	0.7
7	2.5 ± 0.4	0.3 ± 0.2	31	4.4
30	2.0 ± 0.3	0.4 ± 0.2	15	2.8
2	1.5 ± 0.5	0.7 ± 0.7	5.3	1.1
26	2.3 ± 0.3	0.3 ± 0.3	12	6.5

S_X : 0.5-7 keV flux in units of 10^{-14} erg s^{-1} cm^{-2}
L_X : de-absorbed bolo. X-ray luminosity, 10^{43} erg s^{-1}

THE L_X-T_X RELATION FOR INTERMEDIATE-REDSHIFT GROUPS

Scaling relations identify divergence from self-similarity due to non-gravitational effects (pre-collapse heating, galactic/AGN feedback, radiative cooling). Evolution in scaling relations at group (rather than cluster) scales is a powerful diagnostic because these non-gravitational effects are more important at smaller mass scales. A small number of group have been observed at intermediate redshift with *XMM-Newton* (Willis et al. 2005, Pierre et al. 2006, Jeltema et al. 2006), and they show little if any evolution in the L_X-T_X scaling relation.

The large intrinsic scatter in the L_X-T_X relation requires a large sample of groups to distinguish between various models. Our full sample will double the number of groups observed in this redshift range. The first five groups have properties consistent with the observed L_X-T_X relation (see Figure 3). They lie in a region on the faint end of the cluster population and bright end of the typical group population, similar to the sample of Jeltema et al. (2006).

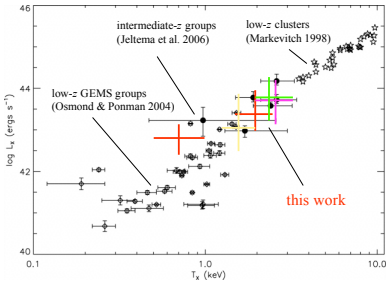


Figure 3. L_X-T_X relation, from Jeltema et al. 2006.

FUTURE WORK

- increase sample: observe all extended X-ray sources in XBootes field brighter than 2×10^{-14} erg s^{-1} cm^{-2}
- incorporate improved XIS calibration products now available (contamination, CTI, gain)
- point source contamination in *Suzaku* data: estimate contribution/cosmic variance, model point sources based on XBootes snapshot
- construct optically-selected group sample from NDWFS, AGES, maxBCG surveys

REFERENCES

Jeltema et al. 2006, ApJ, 649, 649
Kenter et al. 2005, ApJS, 161, 9
Markevitch 1998, ApJ, 504, 27
Osmond & Ponman 2004, MNRAS, 350, 1511
Pierre et al. 2006, MNRAS, 372, 591
Willis et al. 2005, MNRAS, 363, 675

SPECTRAL MODELING

The *Suzaku*/XIS group spectra were extracted from circular apertures of 1 Mpc radius at the group redshift. Point sources brighter than 10^{-14} erg s^{-1} cm^{-2} were masked out. Due to vignetting and non-uniform OBF contamination, the X-ray background was fit simultaneously to a region outside the group aperture, using the appropriately-weighted ARF. The full model is shown below in Figure 1 and included in the fits shown in Figure 2. Detector background was corrected using the accumulated *Suzaku* night Earth background data. The exposure-corrected flux maps are shown in contours on the NDWFS R-band images in Figure 2. The *Chandra*/ACIS spectrum was extracted from a similarly-sized aperture, with a nearby region used as the background. Point sources were masked by hand.

The diffuse group emission was modeled using the APEC plasma code with variable temperature and abundance. Fitting results are shown in Table 2. Group kT ranges from 0.7-2.5 keV with abundances of 0.1-0.7 solar.

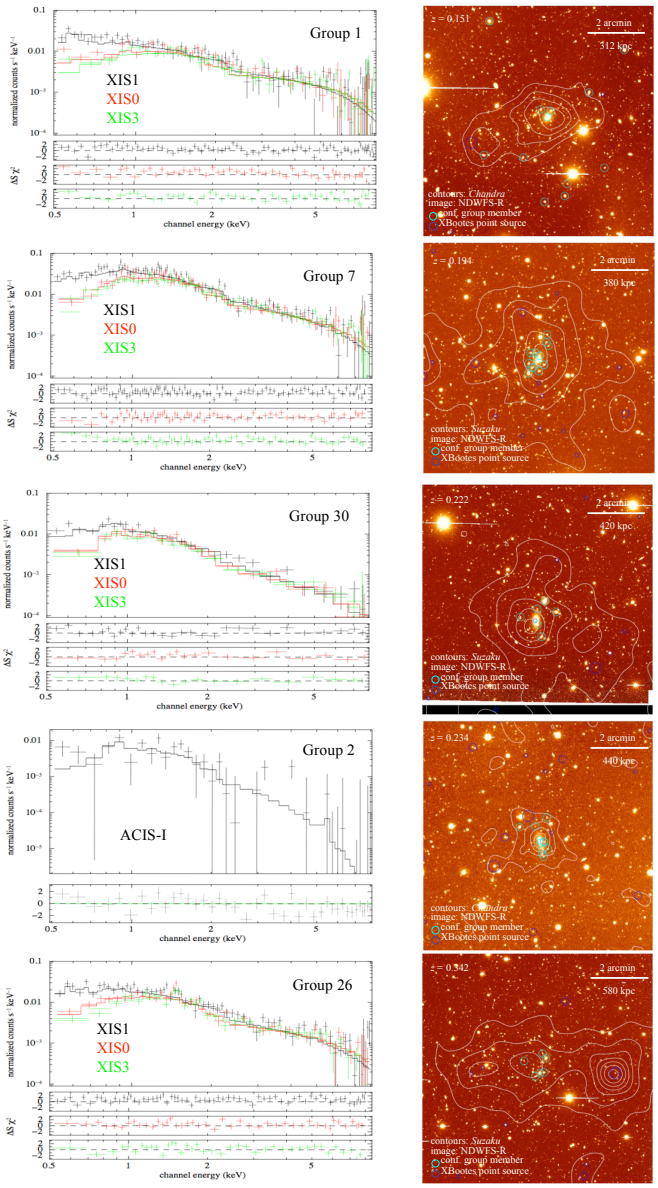


Figure 2. Spectra and images of the observed groups.