Suzaku Study of Hard X-ray Emission from Nearby Galaxy Clusters

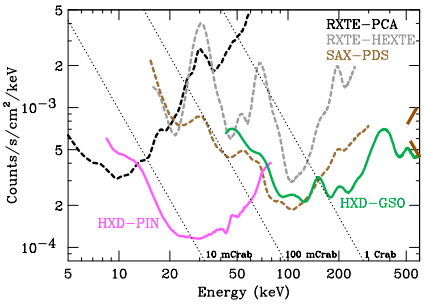
T. Kitaguchi[1], K. Nakazawa[1], K. Makishima[12], M. Kawaharada[2], N. Ota[3], M. Kokubun[3], N. Yamasaki[3], N. Kawano[4], Y. Fukazawa[4], K. Sato[5], T. Ohashi[6], K. Murase[7], Y. Urata[7], M. Tashiro[7], A. Furusawa[8], and *Suzaku* team

1. Univ. of Tokyo, 2. RIKEN, 3. ISAS/JAXA, 4. Hiroshima Univ., 5. Tokyo Univ. of Science, 6. Tokyo Metropolitan Univ., 7. Saitama Univ., 8. Nagoya Univ.

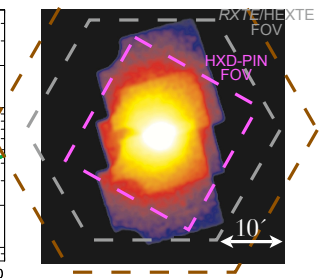
Introduction

We present results on the *Suzaku* study of hard X-ray emission from nearby relaxed galaxy clusters. Non-thermal emission from merging clusters such as Coma and Abell 2256 has been reported using *BeppoSAX*/PDS, but that from relaxed clusters has hardly been studied so far either observationally or theoretically. Using the hard X-ray detector (HXD) onboard *Suzaku*, we measured hard X-ray spectra of three rather relaxed nearby clusters; the Perseus cluster, the Centaurus cluster, and Abell 1060. Through detailed investigation on statistical and systematic errors, we conclude that the signals can be explained by contributions from the thermal emission.

1. Advantages of *Suzaku*/HXD-PIN



Residual background level
(Kokubun et al., 2006)



Suzaku/XIS image of the Centaurus cluster
(Ota et al., 2006)

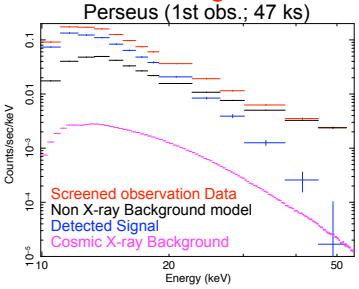
The background spectra observed in orbit is very low (< 10 mCrab), especially in the HXD-PIN energy band. Thanks to its very low background, the HXD-PIN can achieve ~0.5 mCrab sensitivity with current background modeling accuracy. Another key characteristics of the HXD is its narrow FOV of 35′ in FWHM. With this narrow beam size, we can reduce contaminated point sources.

2. Data Reduction

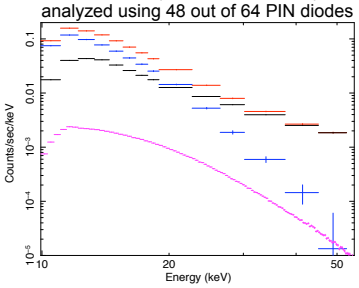
- Rev 1.2 processed data are utilized.
- Non X-ray background of HXD-PIN is subtracted by use of non X-ray background model created by HXD team.
- The extra-galactic CXB component is evaluated using the HEAO-1 value (Boldt., 1987).
- Data are screened with the standard selection criteria; COR < 8 GV, Elevation > 5° , and no SAA passing.

3. Detected Signals

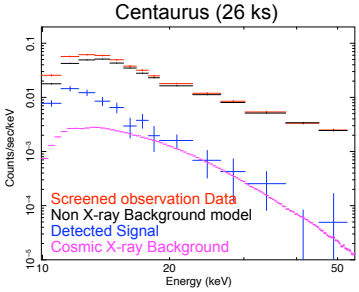
Perseus (1st obs.; 47 ks)



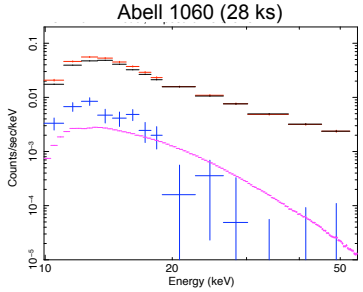
Perseus (2nd obs.; 121 ks)
analyzed using 48 out of 64 PIN diodes



Centaurus (26 ks)

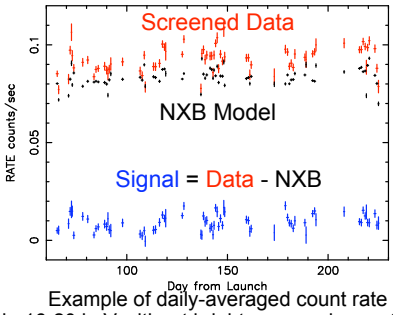


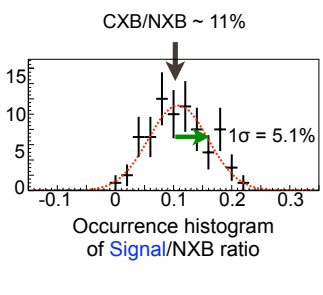
Abell 1060 (28 ks)



Using the HXD-PIN, we have detected positive signals above the non X-ray background from the Perseus cluster, the Centaurus cluster, and Abell 1060, in the energy range of 10-50, 10-20, and 10-15 keV, respectively. The spectra shown above includes only statistical errors, not including systematical errors.

4. Systematic Error Estimation





Example of daily-averaged count rate in 16-20 keV without bright source observations

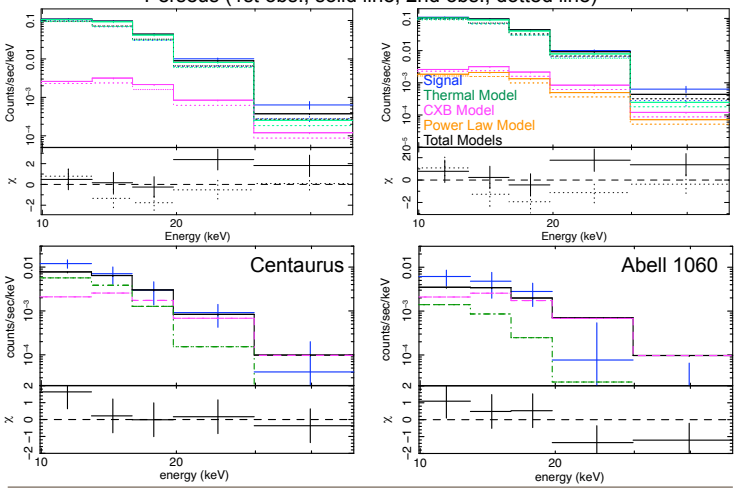
Energy Band (keV)	10-13	13-16	16-20	20-30	30-50
Standard Deviation (%)	5.2	4.8	5.1	3.7	3.1
CXB/BGD (%)	9.0	9.8	11	8.2	2.1

Systematic errors in several energy bands

Comparing daily-averaged count rate of the non X-ray background model with the detected signals, the systematic error is considered to be ~5% (1σ = 68% confidence level) for each energy bins.

5. Spectral Analysis

Perseus (1st obs.; solid line, 2nd obs.; dotted line)



Object	Perseus		Centaurus	Abell 1060
Temperature (keV)	6.56 ± 0.03	6.56 (fix)	3.8 (fix)	3.3 (fix)
Emission Measure	0.70 ± 0.07	0.66 ± 0.02	0.11 (fix)	0.043 (fix)
Norm of PL with Γ = 2	0.0 (fix)	(3.0 ± 2.5)E-3	0.0 (fix)	0.0 (fix)
χ^2/v	15.2/8	13.8/8	2.9/5	5.0/5

Including the systematic error estimated above, the detected signals from the Perseus cluster is fitted with a thermal bremsstrahlung model. Best-fit temperature of kT (= 6.56 keV) is in good agreement with past measurements. If a single powerlaw with a photon index of 2 is added to the thermal model with the temperature fixed, powerlaw luminosity is given as (5 ± 4) x 10^{43} erg/s (error is 1σ).

In the case of the Centaurus cluster and Abell 1060, the excess HXD-PIN flux can be explained by the the thermal emission model determined from *ASCA* results. Therefore, the detected signals can be accounted for by the thermal intracluster medium emission, with no need for excess signals of non-thermal or hotter components. Considering that the total HXD-PIN background flux is ~10 mCrab, and the statistical and systematic errors are ~2% and 5%, respectively. we quote the 1σ (68%) upper limit luminosity on any non-thermal emission with a photon index of 2 at 3 x 10^{42} erg/s (20-80 keV) for these two relaxed clusters.

Summary

Thanks to the low background of the HXD-PIN, hard X-ray spectra have been determined with high significance from the Perseus cluster, the Centaurus cluster, and Abell 1060. Temperature determined in the energy range of 10-50 keV is 6.5 keV for the Perseus cluster, in good agreement with results in the energy range below 10 keV. Non-thermal luminosity is inferred to be (5 ± 4) x 10^{43} erg/s. The HXD-PIN spectra of the remaining two objects can be accounted for by the thermal ICM emission as well. The 1σ upper limit on 20-80 keV non-thermal luminosity is obtained as 3 x 10^{42} erg/s for both objects.

Reference

E. Boldt., IAUS, 1987
L. P. David et al., ApJ, 1993
H. Ezawa et al., PASJ, 2001
Y. Fukazawa et al., ApJ, 2000
M. Kokubun et al., PASJ, 2006
S. Molendi et al., A&A, 2002
K. Nakazawa et al., PASJ, 2007
N. Ota et al., PASJ, 2006
J. Sanders et al., MNRAS, 2005
K. Sato et al., PASJ, 2006
I. Takahashi, Ph-D thesis, 2004
T. Tamura et al., ApJ, 2000