ANALYSIS OF LOW SURFACE BRIGHTNESS X-RAY CLUSTERS OF GALAXIES

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ABSTRACT

We present the analysis of a sample of 7 low surface brightness (LSB) X-ray clusters (4C+34.16, A1674, A1882, A194, A2638, A2690, and NGC5171) observed with XMM-Newton. These clusters are nearby ($0.02 < z < 0.14$) but have a low X-ray flux which is less than 10^{-12} erg sec^{-1}cm^{-2}. The LSB clusters are considered to be a new class of objects which are in the process of formation. We investigate the X-ray properties of these clusters.

We find 3 of 7 clusters shows a low metal abundance of $<$0.2 solar. Our result indicates that in these clusters not enough metals are supplied from member galaxies. The low metal abundance and LSB suggest that these clusters are still at an early stage of evolution.

Key words: Galaxy clusters; Low surface brightness; XMM-Newton .

1. INTRODUCTION

The evolution of the metal abundances in the intracluster medium (ICM) is historically studied by many authors (e.g., Mushotzky & Loewenstein, 1997; Tozzi et al., 2003). These results suggest that there is no evolution of the mean iron abundance out to $z \sim 1$ and that most of the cluster metals were produced at $z > 1$. These studies have mainly been performed for the X-ray luminous galaxy clusters.

However, Katayama, Hayashida, and Nishino (2005) observed a low surface brightness (LSB) X-ray clusters A1674 and found that some properties of A1674 are different from those of X-ray luminous galaxy clusters. The metal abundance of A1674 ($0.07(< 0.2)\,Z_{\odot}$) is lower than that of other clusters. Katayama, Hayashida, and Nishino also showed that the gas fraction $f_{\rm gas}$ of A1674 is only 1%. The low metal abundance and the low gas fraction suggest that this cluster is still at an early stage of evolution.

In order to investigate X-ray properties of other LSB clusters, we analyzed a sample of LSB clusters observed with XMM-Newton. Throughout this paper, we assume a cosmology with $\rm H_0 = 70\,km\ s^{-1}\ Mpc^{-1}$, $\Omega_{\rm m} = 0.27$ and $\Lambda = 0.73$.

2. SAMPLE

We selected sample clusters from the XMM-Newton archival data. In order to select a LSB cluster, we used following selection criteria: (1) Cluster redshift is less than 0.2, (2) X-ray flux is less than 10^{-12} erg sec^{-1}cm^{-2}, and (3) Spatially averaged temperature is more than 1 keV. From about 400 archival data of clusters of galaxies, we selected 7 clusters including A1674.

3. SPECTRAL ANALYSIS

We screened the event files following the method in Katayama et al. (2004). In order to investigate the diffuse X-ray emissions of these clusters, we first detected point sources using the SAS task eboxdetect. We excluded a circular region of radius $15^{''}$ around detected sources. We used the blank sky data compiled by Read & Ponman (2003) as a background data. Fig. 1 shows the EPIC spectra of NGC5171. We fitted these spectra with the APEC model modified by Galactic absorption. The neutral hydrogen column density is fixed to the Galactic values. Fig .2 shows the error contours for metal abundance versus cluster temperature.

Table 1 shows the best-fit parameters for the spectrum fit. Although we can constrain only the upper limit due to the poor photon statistics for some clusters, the fitting results suggest that the metal abundance of 3 clusters (A1674, A2638, and NGC5171) are $<$0.2 solar.

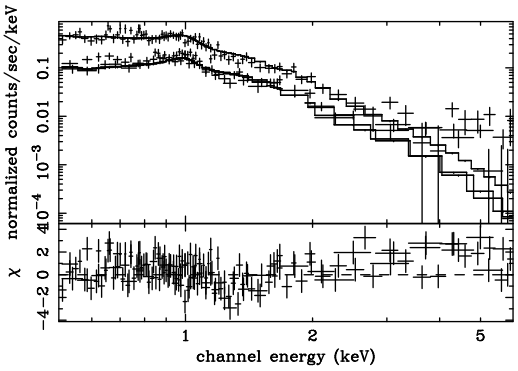

Figure 1. EPIC spectra of NGC5171.

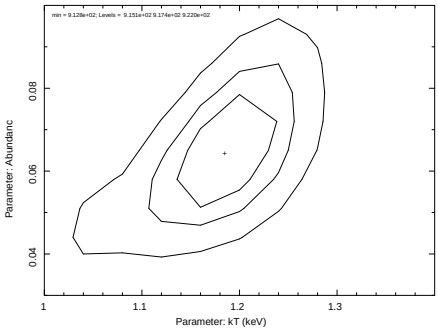

Figure 2. 68%, 90%, and 99% error contours for the cluster temperature and abundance of NGC5171.

4. COMPARISON WITH X-RAY BRIGHT CLUSTERS

Fig. 3 shows the temperature-iron abundance relation obtained from ASCA observation (Matsumoto et al., 2000). We find 3 of 7 clusters show a low metal abundance of $<$0.2 solar. Our result indicates that in these clusters not enough metals are supplied from member galaxies.

5. SUMMARY

We analyzed 7 LSB X-ray clusters. From the spectral analysis, we find that 3 of 7 clusters shows low metal abundance of $Z<0.2Z_{\odot}$. The low metal abundance and LSB suggest that these clusters are still at an early stage of evolution.

In order to investigate the LSB clusters, a low background detector is crucial. The X-ray CCD camera onboard Suzaku (X-ray Imaging Spectrometer: XIS) has an advantage that the background level is lower in comparison with Chandra or XMM-Newton Katayama et al. (2004). This advantage of Suzaku/XIS will reveal the detail of the early stage of cluster evolution.

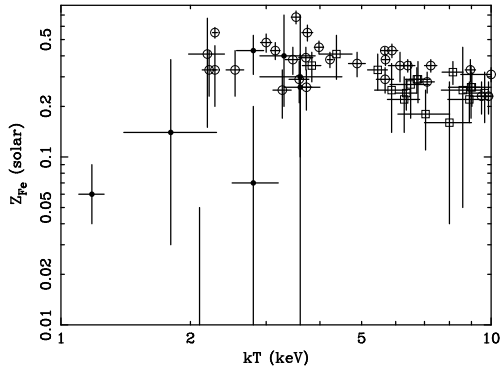

Figure 3. Comparison of temperature-iron abundance relation. Open circles and open squares are correspond to nearby cluster samples and distant cluster samples, respectively. Closed circles are 7 LSB clusters.

Table 1. Best-fit parameters of sample clusters.

Target	redshift	f_X [10^{-13} erg/s/cm^2]	kT [keV]	Z
4C+34.16	0.078	5.64±0.06	$3.3^{+0.6}_{-0.4}$	$0.4^{+0.3}_{-0.2}$
A1674	0.107	2.83±0.09	$2.8^{+0.4}_{-0.3}$	$0.07(<0.20)$
A1882	0.137	3.53±0.25	$3.6^{+0.9}_{-0.7}$	$0.3^{+0.4}_{-0.3}$
A194	0.018	7.74±0.35	$3.6^{+0.4}_{-0.3}$	$0.26^{+0.15}_{-0.16}$
A2638	0.083	1.44±0.03	$2.1^{+0.2}_{-0.2}$	$0.00(<0.05)$
A2690	0.013	0.69±0.09	$1.8^{+0.5}_{-0.4}$	$0.14^{+0.24}_{-0.11}$
NGC5171	0.023	1.40±0.05	$1.18^{+0.08}_{-0.08}$	$0.06^{+0.03}_{-0.02}$

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