Suzaku observations of Kα lines of iron from intracluster medium of the Coma cluster

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Abstract

We studied temperature structure of the intracluster medium, possible bulk motions, and Fe and Ni nucleosynthesis in the Coma cluster with Suzaku. The temperatures derived from observed ratios of H-like and He-like Fe Kα lines agree well with those from spectral fitting with the single-temperature APEC model in the 1.0–8.0 keV and 5.0–8.0 keV bands. Since the line ratio is a strong function on plasma temperature, the observed consistency indicates that single-temperature component dominates the spectrum from each cell region. The observed values of central energy of the He-like Fe line are constant within 1000 km s^{-1}, which corresponds to a calibration error. Comparing with the sound velocity of the intracluster medium, 1500 km s^{-1}, we can verify the derived total mass in the cluster based on hydrostatic ICM equilibrium. These results on temperature and velocity structures suggest that the core of the Coma cluster reached in a fairly relaxed state after the recent merging. The observed Fe abundance of the intracluster medium is almost constant at 0.45 solar. Therefore, the gas should have been well mixed during mergings. The Ni/Fe ratio is found to be close to the solar ratio. In the nucleosynthesis of Ni and Fe, there is no obvious difference the cluster and the Galaxy.

Key words: galaxies: clusters:individual(The Coma cluster) — X-rays: galaxies— X-rays: ISM

1. Introduction

Thanks to its low background, Suzaku is most sensitive to Kα lines of Fe. We studied temperature structure of the intracluster medium, possible bulk-motions, and Fe and Ni nucleosyntheis in the Coma cluster observed with Suzaku.

Clusters of galaxies are thought to grow into larger systems through complex interactions between smaller systems. Signatures of such merging events may manifest themselves in temperature and density inhomogeneities in the intracluster medium (ICM), and bulk motions.

Excess Ni abundances of the ICM are reported by Beppo-SAX and ASCA observations (de Grandi & Molendi 2002 ; Baumgartner et al. 2005). In contrast, fitting with APEC model of XMM-Newton spectra of the Perseus cluster did not need a excess Ni abundance (Churazov et al. 2004). In dense cooling core regions, the effect of resonant scattering of He-like Fe line has been discussed. Since this effect is negligible in the Coma cluster, the cluster is suitable to study Ni abundance.

The XMM-Newton observations revealed the projected temperature distribution around two central galaxies are remarkably homogeneous, suggesting that the core is mostly in a relaxed state (Arnaud et al. 2001). A hot front in the south-west and a cold region in south-east were found. The Coma cluster has a cluster-wide synchrotron radio halo, emitted from the relativistic electrons due to merging (Feretti et al. 1998). Non-thermal emission at Hard X-ray energies in the Coma cluster was studied with Suzaku HXD and XMM-Newton EPIC-pn (Wik et al. 2009). Statistically significant evidence were not found.

2. Observations and Data Analyss

The central region of the Coma cluster was observed with the XIS onboard the Suzaku satellite in two pointings, centered on the X-ray peak and 15' west offset on May 30–June 4, 2006. We devided $18' \times 18'$ square XIS field of view of the central and the offset regions into 4×4 and 2×2 cells, respectively. The background spectrum for each cells was derived by integrating over the same detector region of a blank-sky data, Lockman Hole, observed on May 17-19, 2006. We use the solar abundances by Lodders (2003). Errors are quoted at 90% confidence.

3. Results and Discussions

3.1. Gas bulk motions

As shown in Fig. 1, the measured redshifts are consistent with the optical one, $z_{\rm cl} = 0.0231$, within the calibration errors(refer to ± 0.002 in the redshift). The dispersion of gas bulk motions $\sigma_v < 1000$ km s^{-1}, with 90% calibration errors. This shows the bulk velocity is less than the thermal velocity of the gas, 1500 km s^{-1}. We can verify the derived total mass in the cluster based on hydrostatic ICM equilibrium.

3.2. Temperature Structure

The continuum emission and the ratio of He-like Kα to H-like Kα line strengths should have different dependence of plasma temperature. Our analysis shows that the spectral fitting using 1.0–8.0 keV energy range and the ratio of strengths of Fe Kα lines gave nearly the same temperatures(Fig. 2, Fig. 3). Thus, we conclude that a single-temperature component dominates the spectra accumulated over the each cell region, and the central region of the Coma cluster is nearly isothermal at 8.0 keV.

3.3. Fe Abundance

The Fe abundance is nearly constant in the observed region, ~ 0.45 times than that of the Sun. This result shows the gas should have been well mixed during mergings and the effect of resonant scattering of He-like Fe line is negligible. Considering the results of §3.1 and §3.2, these results indicate that the Coma cluster in the central region reached nearly relaxed state after the recent merging.

3.4. Ni Abundance

We obtained a normalization of a sum of He-like Fe-Kβ and Ni-Kα lines in the central field. Subtracting a theoretical ratio of line strength of Fe Kβ to Fe Kα depend on temperature, we derived a contribution from Ni. The Ni/Fe ratio is close to the solar ratio. From this result, we conclude that in thenucleosynthesis of Ni and Fe, there is no obvious difference between the cluster and the Galaxy.

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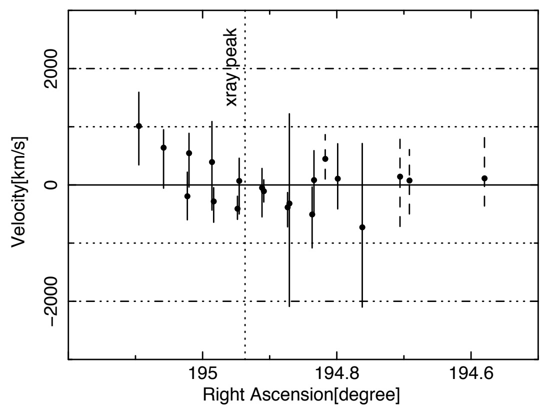

Fig. 1. Distribution of radial ICM velocity derived from the spectral fitting over 5.0–8.0 keV energy range with the APEC model in the 20 cells. The solid and dashed crosses correspond to center and offfset regions, respectively.

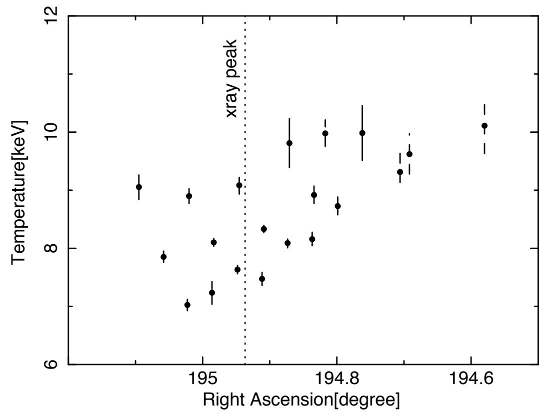

Fig. 2. Observed Temperature, derived from the spectral fitting over 1.0–8.0 keV energy range, plotted against the right ascension. The solid and dashed crosses correspond to center and offfset regions, respectively.

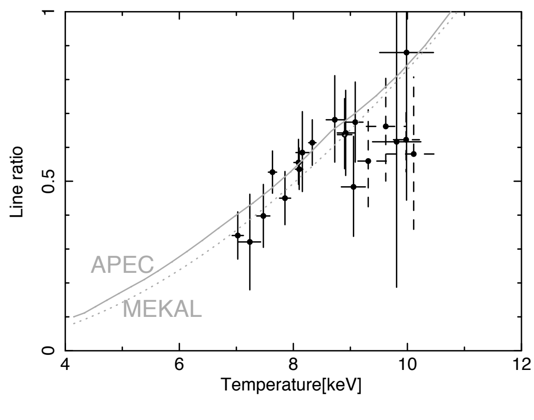

Fig. 3. Intensity ratio of H-like and He-like Fe Kα lines in each cell region is plotted against the derived temperatures from spectral fitting in the 5.0–8.0 keV band. The solid and dashed crosses correspond to center and offfset regions, respectively.The solid and dotted lines correspond to theoretical line ratio from the APEC(solid) and MEKAL(dotted) model, respectively.