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Metal abundances in the ICM associated with a medium-redshift cluster of galaxies MS 1512.4+3647 observed with Suzaku

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Abstract. We observed a medium-redshift cluster of galaxies MS 1512.4+3647 (z = 0.37) with Suzaku for 209 ks. ASCA observation reported that MS 1512.4+3647 is rather bright in X-rays and that the ICM temperature is low (2.85 keV) with high metal abundance (1.1 solar). Therefore, MS 1512.4+3647 is one of the best targets to detect metal abundances not only for Fe but also for alpha elements. Thanks to the stable and low background level of Suzaku XIS, emission lines from highly ionized ions such as Ne, Mg, Si, S, Fe and Ni were significantly detected. Using a thin thermal plasma model, the abundances of these elements are determined with uncertainties less than 50%. This is one of the first results of abundance determination for alpha elements in the ICM associated with medium-redshift clusters. The abundance ratio relative to Fe is consistent with low-redshift clusters. Implications for metal enrichment history of this cluster will be discussed.

Key words. galaxies: clusters: individual (MS 1512.4+3647) – X-rays: galaxies: clusters – X-rays: ICM

1. Introduction

The intracluster medium (ICM) is constrained within the large gravitational potential of clusters of galaxies, and enriched with metals which originate from supernova activities (SNe). There are two types of SNe, SN Ia and SN II, which correspond to the explosion of accreting gas onto a white dwarf from companion star, and the explosion of gravitational core collapse of a large star, respectively. SN Ia creates a lot of iron family elements, on the other

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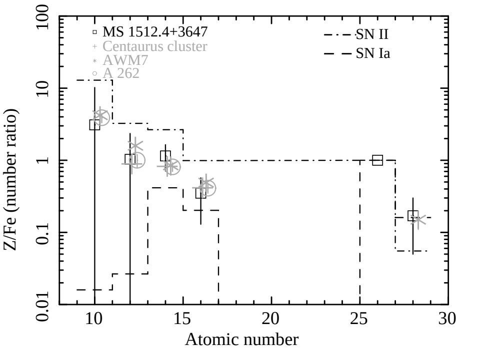

Fig. 1. The abundance number ratio to Fe for MS1512.4+3647 (squares) compared to nearby clusters. Dashed and dash-dot lines indicate SNe yields.

hand SN II creates mainly alpha elements such as Mg, Si and S.

Chandra and XMM-Newton studied a Fe abundance evolution using a large number of clusters with $0 < z < 1.2$, and reported abundance dropping of about 50% from $z = 0$ to $z = 0.5$. Recently, Suzaku has studied the metal abundances of alpha elements of nearby clusters (e.g. Sato et al. 2010), thanks to low and stable background level. Combining the Suzaku results with SNe nucleosynthesis model (Iwamoto et al. 1999; Nomoto et al. 2006), the number ratio of SNe II to Ia was found to be ~ 3.5 in nearby clusters (Sato et al. 2007). The determination of metal abundance for each element in the ICM at high redshift is needed to resolve the chemical enrichment history of the ICM. Then we selected MS 1512.4+3647 as a target, which is bright ($L_X = 3.6 \times 10^{44}$ erg s^{-1} in 2.0–10.0 keV), cool (3 keV), and metal rich (1.1 solar) at an intermediate redshift of $z = 0.372$ (Ota 2000).

Through the paper we used $H_0 = 71$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.27$.

2. Observation and data reduction

A Suzaku observation was performed from end of 2007 to early 2008 with exposure of 269 ks (ObsID 802034010). The three CCD camera (XIS0, 1, 3) were operated in normal mode with average pointing direction of (α, δ)=(15h14m25s.4, 35°37′11″.3). All observation data are re-processed referring to the latest calibration database. An effective exposure of 209 ks was obtained.

3. Results

The XIS image is contaminated by a number of point sources. These sources are detected and excluded using Chandra archival observation data of MS 1512.4+3647. In the spectral analysis, we extracted a ICM spectra from 0.6$r_{\rm virial}$ circular region, and the non-X-ray background is estimated using night Earth observation. The cosmic X-ray background and Galactic foreground emission are estimated from outer region of more than 1.1$r_{\rm virial}$ of MS 1512.4+3647. We detected a significant signal from heavy metals of Ne, Mg, Si, S, Fe and Ni with a temperature of 3.3 keV.

Fig 1 shows the abundance number ratio of Ne, Mg, Si, S and Ni to Fe. The ratio found in nearby clusters are also plotted. The ratio of MS 1512.4+3647 is consistent with that found in nearby clusters. In fig 1, SNe Ia (Iwamoto et al. 1999) and SN II (Nomoto et al. 2006) yielded models are also plotted. The observed ratios are between these models; therefore this indicates that both contribute to enrich the ICM. From these results, we can limit a star formation history through the comparison with theoretical models; this is still a working in progress.

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