Suzaku and XMM-Newton Observations of the Metallicity Distribution in the Intracluster Medium of the Fornax cluster

Hideyoshi Murakami[1], Kyoko Matsushita[1], Madoka Komiyama[1], Kosuke Sato[2], Ryo Nagino[1], Takaya Ohashi[3], Noriko Yamasaki[4], Yoh Takei[4] and Kazuhiro Nakazawa[5]

[1] Department of Physics, Tokyo University of Science, 1-3 Kagurazaka, Shinjuku-ku, Tokyo 162-8601
[2] Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa, Ishikawa 920-1192
[3] Department of Physics, Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji, Tokyo 192-0397
[4] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510
[5] Department of Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033
E-mail(HM): j1208669@ed.kagu.tus.ac.jp

Abstract

The metallicity distribution in the intracluster medium (ICM) of the Fornax cluster was studied with Suzaku and XMM-Newton. The abundances of O, Mg, Si, S, and Fe within a radius of $0.2r_{180}$ were measured with high accuracy with Suzaku. The abundance of Fe and the gas mass within a radius of $0.3r_{180}$ were measured with XMM-Newton.

The oxygen and iron mass-to-light ratio (OMLR, IMLR) within $0.1r_{180}$ are over an order of magnitude lower than those of rich clusters and some relaxed groups of galaxies like the NGC 5044 group. The metal mass to light ratios outside $0.1r_{180}$ increases with radius, and may become comparable to those of the NGC 5044 group at 0.4–$0.5r_{180}$. In the Fornax cluster, the asymmetric X-ray emission may point to large-scale dynamical evolution, which might have hampered the strong concentration of hot gas in the center.

Key words: X-rays: galaxies: clusters — intracluter medium — metallicity

1. Introduction

Groups and poor clusters of galaxies are different from richer systems in that iron mass-to-light ratio (IMLR) of poorer systems are systematically smaller than that in rich clusters (Makishima et al. 2001). The metal distribution in the intracluster medium (ICM) may be used as a tracer of the history of the gas heating, since both metal enrichment and heating timescales determine the metal distribution in the ICM.

With Suzaku, the central region, $<0.1r_{180}$, of the Fornax cluster, which is a nearby poor cluster with an ICM temperature 1.3–1.5 keV, has studied (Matsushita et al. 2007a). The X-ray emission of the Fornax cluster shows asymmetric spatial distribution, and the cD galaxy, NGC 1399, is offset from the center (Scharf et al. 2005; Machacek et al. 2005). The metals in groups and poor clusters may be much more extended than rich clusters which may contain all of the metals synthesized in galaxies. Therefore, we observed outer regions of the Fornax cluster.

We use the Hubble constant $H_0 = 70$ km s^{-1} Mpc^{-1}. The distance to the Fornax cluster is $D_L = 19.8$ Mpc, and $1'$ corresponds to 5.70 kpc. The virial radius, $r_{180} = 1.95\ h_{100}^{-1}\sqrt{k\langle T\rangle/10\ \mathrm{keV}}\ Mpc$ (Markevitch et al. 1998; Evrard et al. 1996), is about 1 Mpc for the average temperature $k\langle T\rangle = 1.3$ keV. We use the new abundance table from Lodders et al. (2003). Unless otherwise specified, errors are quoted at 90% confidence.

2. Observation and Data analysis

Suzaku and XMM-Newton performed offset pointing observations of the Fornax cluster up to $0.2r_{180}$ and $0.3r_{180}$, respectively. We divided the fields into four direction, North(N); South(S); Northeast(NE); Northwest(NW).

We assumed the ICM consists of a single temperature vapec model (Smith et al. 2001) and fitted spectra of XIS. The metal abundances of He, C, N, and Al were fixed to the solar values. We divided the other metals into six groups, O; Ne; Mg; Si; S, Ar and Ca; Fe and Ni, and allowed them to vary.

To determine gas mass, we used 0.8–1.2 keV energy range of XMM-Newton data, where the uncertainties in the background are small.

3. Results and Discussion

The temperatures of the NW and S fields are ~1.3 keV, and those of the NE and N fields are ~1.05 keV.

O, Mg, Si, S and Fe shows similar abundance profiles: about 1 solar around NGC 1399, and about 0.5 solar from 0.02 to $0.2r_{180}$. The value of Fe abundance of 0.5 solar is similar to those in rich clusters and other groups of galaxies (Fig.1). The radial profile of the Fe abundance from 0.1 to $0.2r_{180}$ is almost comparable with other clusters or groups. In more detail, the Fe abundance of NW and NE regions are 0.50–0.56 solar, while those of S and N regions are slightly smaller, at 0.4 solar (Fig.1). The abundance ratios are consistent from the center to $0.2r_{180}$. In average, the abundance ratios of O/Fe, Mg/Fe, Si/Fe, S/Fe are about 0.6, 0.8, 0.8, and 1, respectively, in the solar units (Fig.2).

The radial profiles of integrated IMLR (Fig.3) and OMLR of the Fornax cluster increase with the radius up to $r \sim 0.3r_{180}$, except $r \sim 0.06r_{180}$ where NGC 1404 exists, while those of the NGC 5044 group become flatter from $0.1r_{180}$ to $0.3r_{180}$. The NGC 5044 group, with an ICM temperature of about 1.0 keV, has the largest IMLR and OMLR among groups of galaxies. If the IMLR and OMLR of the Fornax cluster continue to increase with the radius at $r > 0.2r_{180}$, the values may become comparable with those of the NGC 5044 group at ~0.4 r_{180}. Considering that the Fe abundances of the Fornax cluster and NGC 5044 group are similar, the Fornax cluster might have hampered the strong concentration of hot gas in the central region of the cluster, due to recent dynamical evolution.

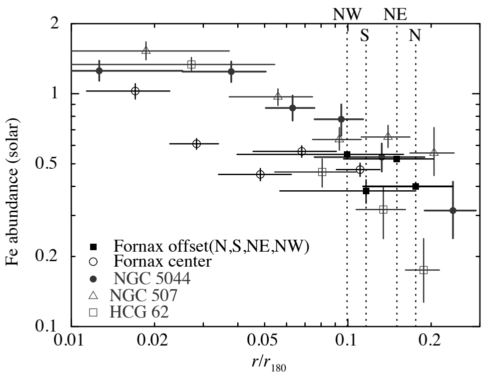

Fig. 1. Radial profiles of the Fe abundance in the Fornax cluster of the four offset fields (black; closed square) and central region (black open circles; Matsushita et al. 2007a), the NGC 5044 group (grey closed circles; Komiyama et al. 2009), HCG 62 group (grey open squares; Tokoi et al. 2008), the NGC 507 group (grey open triangles; Sato et al. 2009a)

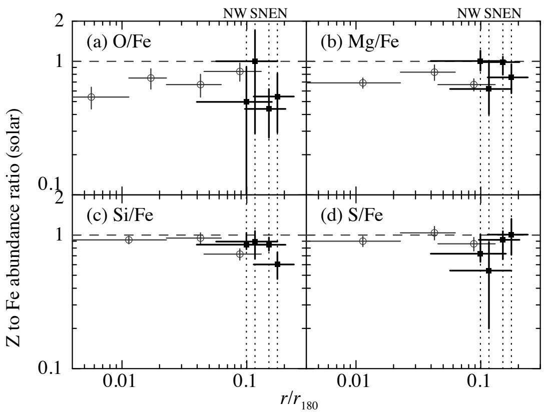

Fig. 2. Radial profiles of (a)O, (b)Mg, (c)Si and (d)S divided by the Fe abundance (in unit of the solar ratio). The central (grey; open circles) and offset fields(black; closed squares).

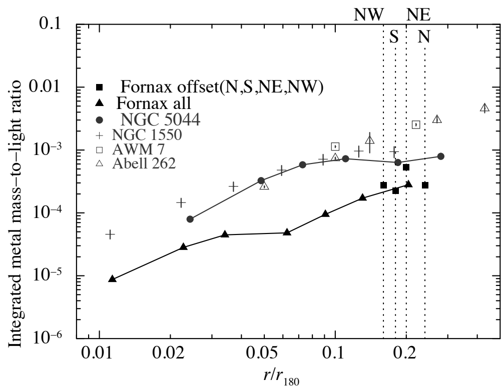

Fig. 3. Radial profiles of integrated IMLR in K-band of the Fornax cluster all (black closed triangles; the gas mass from ROSAT observation (Paolillo et al. 2002)), the Fornax cluster offset (black closed squares; the gas mass from XMM observation), NGC 5044 group (grey closed circles; Komiyama et al. 2009), NGC 1550 group (grey crosses; Kawaharada et al. 2009), AWM7 cluster and Abell 262 cluster (grey open squares and triangles; Sato et al. 2008, 2009b).

References

Evrard, A. E., et al. 1996, ApJ, 469, 494
Kawaharada, M., et al. 2009 ApJ, 691, 971
Komiyama, M., et al. 2009 PASJ, 61, S337
Lodders, K., et al. 2003 ApJ, 591, 1220
Machacek, M., et al. 2005, ApJ, 621, 663
Makishima, K., et al. 2001 PASJ, 53, 401
Markevitch, M., et al. 1998, ApJ, 503, 77
Matsushita, K., et al. 2007a PASJ, 59, 327
Paolillo, M., et al. 2002 ApJ, 565, 883
Sato, K., et al. 2009a PASJ, 61, S353
Sato, K., et al. 2009b PASJ, 61, S365
Sato, K., et al. 2008 PASJ, 60, 333
Scharf, C. A., et al. 2005, ApJ, 633, 154
Smith, R. K., et al. 2001, ApJL, 556, L91
Tokoi, K., et al. 2008, PASJ, 60, 317