Mem. S.A.It. Vol. 85, 388

Memorie della

Fe abundance distribution in the nearby merging groups NGC 7618 & UGC 12491 studied with Suzaku

Ikuyuki Mitsuishi[1], Shin Sasaki[1], Katsuhiro Hayashi[2], Noriko Iijima[1], Mayu Sato[1], and Takaya Ohashi[1]

[1] Department of Physics, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan
e-mail: mitsuisi@phys.se.tmu.ac.jp
[2] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo, Sagamihara, Kanagawa 252-5210, Japan

Abstract. We investigated the Fe abundance distribution in the nearby merging groups NGC 7618 and UGC 12491. Negative abundance gradients towards the outer region were seen in both groups. The Fe abundance decreases by a factor of 2-3 from ∼0.4 solar at $r < 40$ kpc to ∼0.2 solar at $80 < r < 120$ kpc in the NGC 7618 group and from ∼0.3 solar to ∼0.1 solar in the UGC 12491 group. The abundances of Fe in the innermost regions of both groups at $< 0.1\ r_{vir}$ are smaller than those of other group and cluster systems. The Fe abundance values in the bridge regions linking both groups are smoothly connected to the abundance profiles of both groups. Thus, no specific feature associated with the merging event was observed at the spatial resolution of >10 kpc, suggesting that the system is in an early phase of the group-group merger.

Key words. Galaxies: abundances – Galaxies: groups: individual: NGC 7618 & UGC 12491 – Galaxies: interactions – Galaxies: intergalactic medium

1. Introduction

Merging phenomena are one of the most energetic and dramatic events in astrophysics, driving evolution in the hierarchical structure of the Universe both dynamically and chemically. A merging phenomenon gives rise to various observational features at all wavelengths over a wide range of masses and spatial scales. In the most massive ($\gtrsim 10^{14}\ M_{\odot}$) and the largest (≳Mpc) system, i.e., clusters of galaxies, the spatial offset of the centers between the gravitational and the baryonic masses (Clowe et al. 2004), Mpc-scale giant radio halos and arc-shaped radio morphologies, named radio relics, (e.g., Feretti et al. 2012; Cassano et al. 2013) have been observed so far. Also in X-ray observations, one can see temperature and abundance jumps, surface brightness discontinuities across merger shocks and cold fronts and complex morphologies (e.g., Henriksen & Tittley 2002; Owers et al. 2011). In contrast to extensive studies of merging clusters of galaxies, understanding of group-scale merger phenomena has not been well established due to very limited samples.

Even though five groups possess bimodal X-ray peaks which can be a direct proof of a merger among 109 low-redshift group samples (Mulchaey et al. 2003) no groups are possibly experiencing current mergers in terms of the fact that a luminous early-type galaxy is already located on each peak. Kawahara et al. (2011) and Mitsuishi et al. (2013a) discovered ongoing merging groups of galaxies within junctions of galaxy filaments characterized by multiple X-ray peaks where no corresponding early-type galaxy is centered. However, their low fluxes and small apparent diameters did not allow us to extract detailed spatial and spectral information.

NGC 7618 & UGC 12491 are considered to be a group-group merging pair in the local Universe (z~0.017) with a sufficient X-ray flux of several 10^{-12} cm^{-2} s^{-1} in each group and large apparent size of >20 arcmin in diameter. Kraft et al. (2006) showed the existence of a second hotter diffuse gas ($kT\sim2$ keV) other than the hot gas components ($kT\sim1$ keV) associated with NGC 7618 & UGC 12491 themselves. The group gas shows arc-like sloshing cold fronts surrounding each group center and ~100 kpc long spiral tails in both groups induced by the merger (Roediger et al. 2012). Thus, the NGC 7618 & UGC 12491 pair is one of the ideal targets to study X-ray properties of the hot gas involved in the merger event. In this paper, we show the first detailed abundance distribution which is expected to show the mixing process by the merger using *Suzaku* X-ray observatory (Mitsuda et al. 2007) with superior spectral resolution and high sensitivity for emission lines.

2. Observation & data reduction

The *Suzaku* field of view (FOV) covers a 18′×18′ area corresponding to ~390×390 kpc^2 physical size and its aim point is placed at the midpoint between NGC 7618 and UGC 12491, i.e., (RA J2000, DEC J2000) = (349.83°, 42.91°) and (l, b) = (105.52°, -16.82°), as shown in Figure 1. Eight regions were extracted to investigate the spatial distribution of the abundance. Region numbers 1–3 and 8–6 correspond to annular regions with radii of 0–2, 2–4 and 4–6 arcmin, but excluding the bridge region denoted as region numbers 4–5 between the centers of the two groups. Since the whole field in the FOV is contaminated by the hot gas contained in the groups, we use an offset region ~4 degrees away from the main target to evaluate the X-ray background emission. In this paper, a neutral hydrogen column density of the Galaxy is assumed to be 1.1×10^{21} cm^{-2}, based on the LAB survey (Kalberla et al. 2005). We adopt the solar abundance tabulated in Anders & Grevesse (1989). HEAsoft version 6.12 and XSPEC 12.7.0 were utilized.

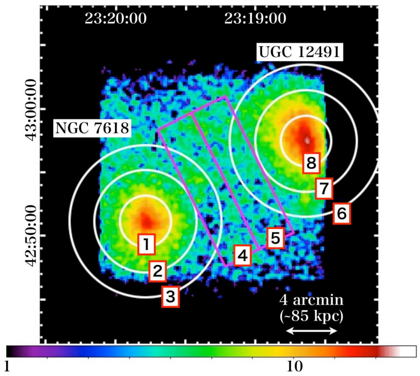

Fig. 1. *Suzaku* X-ray image in 0.5–2.0 keV of the NGC 7618 & UGC 12491 pair. Extracted regions for spectral analysis are shown by white circles with radii of 2, 4 and 6 arcmin from NGC 7618 or UGC 12491 and magenta rectangles between the two galaxies. The number assigned to each region is also shown. Vignetting is not corrected and the scale is logarithmic.

3. Analysis & results

As reported by Masui et al. (2009) and Mitsuishi et al. (2013b), the X-ray background components near the Galactic plane are different from those of high-latitude regions.

A narrow bump-like structure peaked at ~1 keV instead of the Galactic halo emission needs to be taken into account in its spectrum. We confirmed that the spectrum obtained from the offset region was represented well by the typical X-ray background emission in the Galactic plane. To consider statistical and systematic uncertainties on the X-ray background emission, a simultaneous fitting between the

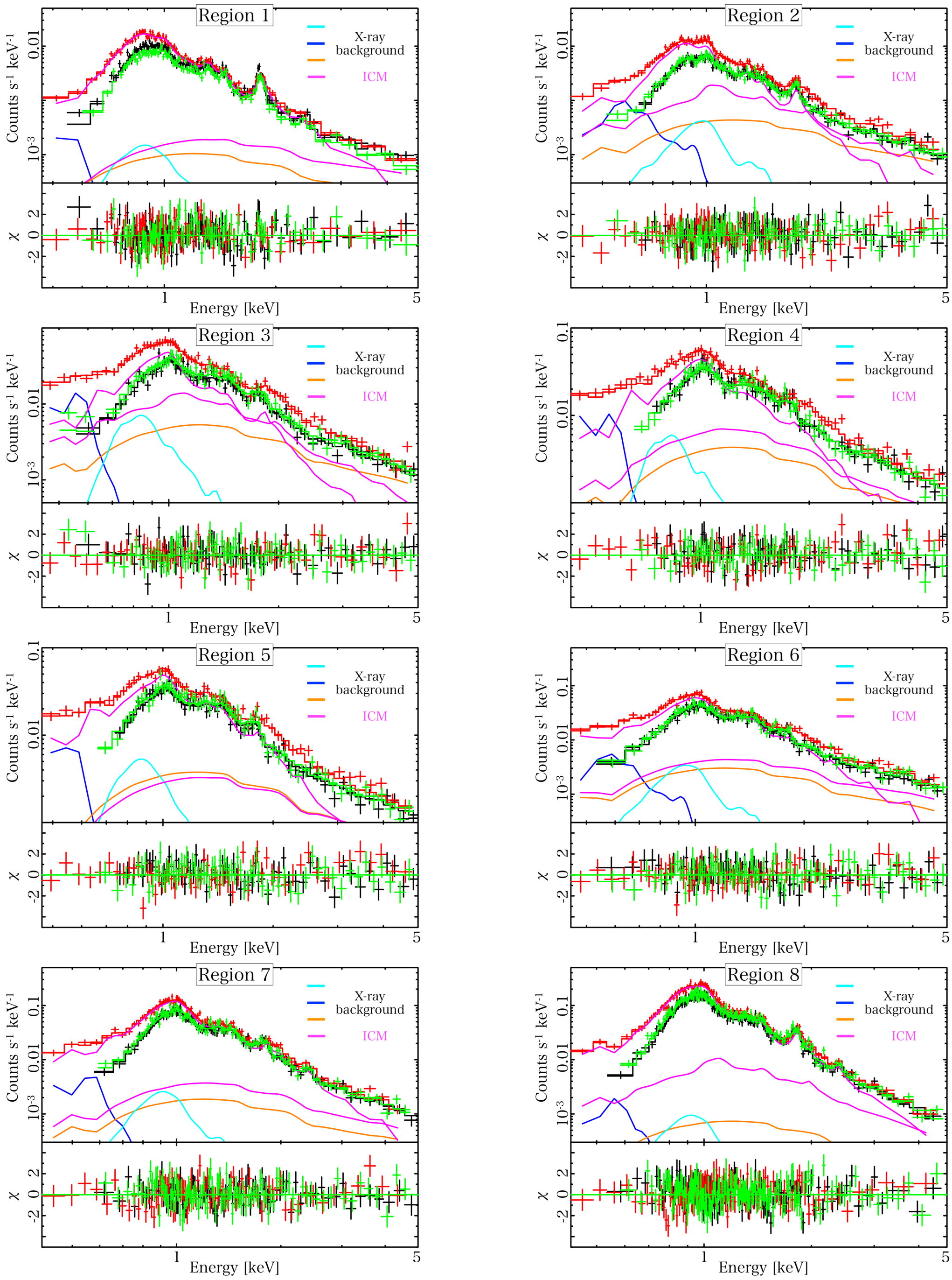

Fig. 2. Resultant spectra obtained from region numbers of 1–8 fitted with the X-ray background emission model (blue, cyan and orange) and the two-temperature thin thermal plasma model for the ICM (magenta). The data (cross) and the best fit models (solid) for three detectors (black, red and green) are shown. The lower panel indicates the residual between the data and the best fit model.

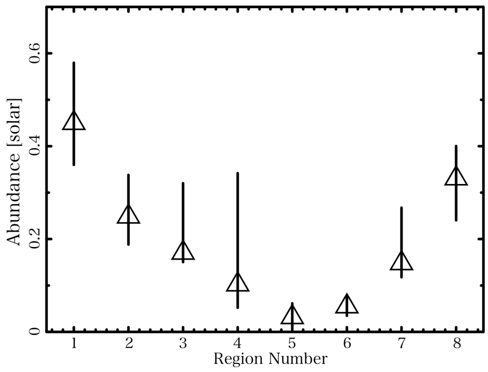

Fig. 3. Resultant Fe abundance distribution in the NGC 7618 & UGC 12491 pair. See Figure 1 for the region number.

target region and the offset region was performed.

Because this X-ray background spectrum cannot reproduce the spectrum of each region one more additional thin thermal plasma model was added to describe the hot gas associated with the intracluster medium (ICM) of the group. In the spectral analysis, we let the Fe abundance, which is expected to be well constrained in the ICM, vary to inquire into the detailed spatial distribution. A two-temperature model was also employed if the goodness of the fit improves significantly even though the temperature is not constrained well. Consequently, the two-temperature model was acceptable for all 8 regions statistically. The Fe abundance between the plasmas was linked to each other assuming the same origin. We confirmed that the Fe abundance in both models are consistent with each other at the 95 % confidence level. We found no discrepancy in the temperature between previous studies (Kraft et al. 2006; Roediger et al. 2012) and this work. Resultant spectra with the best fit models and the Fe abundance distribution are indicated in Figures 2 and 3. In both groups, negative abundance gradients towards the outer region were seen. The abundance of Fe decreases by a factor of 2–3 from ~0.4 solar at $r < 40$ kpc to ~0.2 solar at $80 < r < 120$ kpc in the NGC 7618 group and from ~0.3 solar to ~0.1 solar in the UGC 12491 group. The virial radii of the groups are calculated to be ~500–600 kpc (Mulchaey et al. 2003). Although this negative trend is observed also in other group and cluster systems (e.g., Komiyama et al. 2009; Matsushita 2011) the Fe abundances of the groups within the innermost region (<0.1 r_{vir}) are relatively low. The abundance values in the bridge regions, i.e., region numbers 4 and 5, are smoothly connected to those of the groups and therefore no abundance ”excess” involved in the merger was evident at the spatial resolution of >10 kpc. This feature suggests that the system is in an early phase of the group-group merger, and a significant mixing of the gas is yet to take place.

References

Anders, E. & Grevesse, N. 1989, Geochim. Cosmochim. Acta, 53, 197
Cassano, R., Ettori, S., Brunetti, G., et al. 2013, ApJ, 777, 141
Clowe, D., Gonzalez, A., & Markevitch, M. 2004, ApJ, 604, 596
Feretti, L., et al. 2012, A&A Rev., 20, 54
Henriksen, M. J. & Tittley, E. R. 2002, ApJ, 577, 701
Kalberla, P. M. W., Burton, W. B., Hartmann, D., et al. 2005, A&A, 440, 775
Kawahara, H., et al. 2011, ApJ, 727, L38
Komiyama, M., Sato, K., Nagino, R., Ohashi, T., & Matsushita, K. 2009, PASJ, 61, 337
Kraft, R. P., et al. 2006, ApJ, 640, 762
Masui, K., Mitsuda, K., Yamasaki, N. Y., et al. 2009, PASJ, 61, 115
Matsushita, K. 2011, A&A, 527, A134
Mitsuda, K., Bautz, M., Inoue, H., et al. 2007, PASJ, 59, 1
Mitsuishi, I., Kawahara, H., Sekiya, N., et al. 2013a, ArXiv e-prints
Mitsuishi, I., Sato, T., Kimura, S., et al. 2013b, AAS/High Energy Astrophysics Division, 13, 301.03
Mulchaey, J. S., et al. 2003, ApJS, 145, 39
Owers, M. S., Randall, S. W., Nulsen, P. E. J., et al. 2011, ApJ, 728, 27
Roediger, E., Kraft, R. P., Machacek, M. E., et al. 2012, ApJ, 754, 147