Suzaku Observation of the Metallicity Distribution in the Elliptical Galaxy NGC 4636

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ABSTRACT

NGC 4636, an X-ray bright elliptical galaxy, was observed with Suzaku. Thanks to low background and good energy resolution of the XIS, we succeeded to estimate the foreground Galactic emission accurately, and measure the metal abundance distributions out to ∼28 arcmin (≃ 140 kpc) for O, Mg, Si and Fe for the first time. Metal abundances are as high as >1 solar within 4' and decreases by ∼50% from the center toward the outer region. In addition, the O to Fe abundance ratio is about 0.6∼1.0 solar in all analyzed regions, indicating that metal products by SNe II and SNe Ia have mixed and diffused to the outer region of the galaxy. Furthermore, comparing distribution of metal mass and mass-to-light-ratio with those of other galaxies, we found that metal distributions in NGC 4636 are less extended, possibly due to environmental factors, such as frequency of galaxy interaction. We also confirmed a signature of the resonance scattering of the Fe XVII line in the central region, as reported with the XMM-Newton RGS observation.

KEY WORDS: galaxies: elliptical and lenticular, cD — X-rays: galaxies — X-rays: ISM

1. Introduction

The hot interstellar medium (ISM) in elliptical galaxies is filled with metals ejected by supernovae and stellar mass loss. By accurate analysis of the X-ray spectra of ISM, we can estimate the metallicity distribution and prove the metal enrichment history. In the past, ASCA, Chandra, and XMM-Newton have revealed abundance patterns in the centers of galaxies, however, observations of outer regions, where metals ejected from galaxies are accumulated, are still poor. To understand metal enrichment process, measurements of O, Ne, Mg abundances out to the outer regions are needed. The most suitable detector to satisfy these conditions is the Suzaku/XIS with a better energy resolution and lower background.

NGC 4636 (z = 0.00313; ≃ 17 Mpc) is a bright elliptical galaxy located at the south of the Virgo cluster. X-ray emission from the cluster is weak, therefore, we can study metal enrichment history in an elliptical galaxy. In addition, we can discuss the temperature dependence of metal properties or environmental effects in comparison with other elliptical galaxies, groups and clusters had been observed by the Suzaku/XIS.

2. Observation

Three pointing observations were carried out for study of NGC 4636; Central region just around NGC 4636 X-ray peak, north region at 10' offset to measure metal abundances in the outer region, and 3.2° offset region for estimating the foreground Galactic emission.

3. Analysis and results

For the central region, we extracted spectra of six annular regions centered on the X-ray peak. For the north region, we analyzed the spectrum of a 8'-radius aperture centered on a position at 20' away from the galaxy center.

3.1. Spectral fitting

We fitted NGC 4636 spectra of each region considering the contribution of background. Two-component model for the emission from NGC 4636 is applied; a single-temperature vAPEC model for the ISM and a BREMSS model with a temperature fixed 7 keV for the hard component due to low mass X-ray binaries. We tried to fit with a two-temperature model, however, temperature and abundances are almost the same as that of single-temperature model. Therefore, we treated the results of only the single-temperature model.

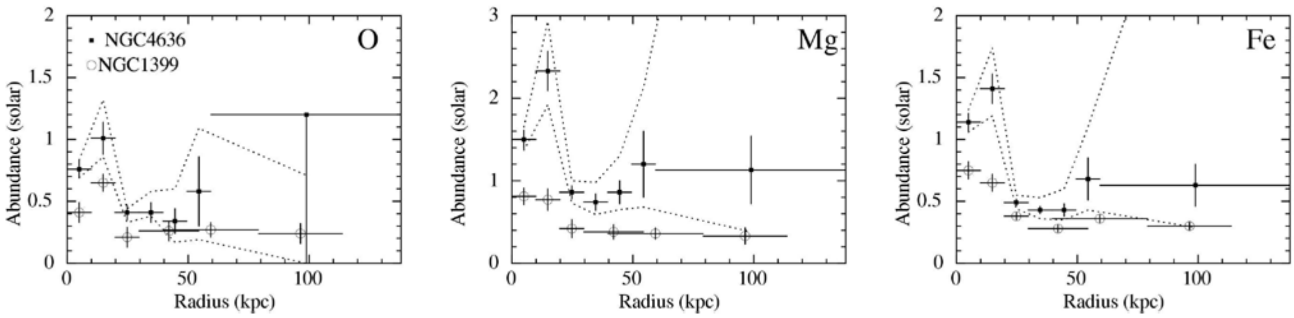

Fig. 1. Metal abundance distributions of NGC 4636 and NGC 1399. Dotted lines indicate the systematic error range due to the uncertainty of the Galactic X-ray emission. The O abundance in 60–140 kpc represents an upper limit.

3.2. Temperature and metal abundance

The temperature in the central region is 0.64 keV and goes up to 0.7-0.8 keV. Figure 1 shows the metal abundance distributions of NGC 4636. Thanks to the high energy resolution of the XIS, O abundance is measured up to 10-12' and Mg, Si and Fe to 12-28' for the first time. All metal abundances are as high as >1 solar within 4' and decrease by ∼50% from the center toward the outer region.

3.3. Resonance scattering in the central region

In the spectrum of the central region, the residual of the spectral fitting has a negative line future around 0.85 keV. This is possibly due to resonance scattering of the Fe XVII line reported from the results of RGS.

4. Discussion

We compared the Suzaku results with those of other X-ray bright elliptical galaxies (NGC 1399 etc).

4.1. Metal abundance distribution

Metal abundances of NGC 4636 exhibit steeper gradient than those of other elliptical galaxies; NGC 1399 (shown in Figure 1), NGC 5044 and NGC 507. This means that NGC 4636 still keeps the metals in aroud the center.

4.2. Radial profiles of the abundance ratio

The abundance ratio O/Fe is about 0.6∼1.0 solar, independent of the radius. This means that O and Fe in the gas diffused to the outside of the galaxy after the products from both SNe II and SNe Ia are well mixed. Moreover, this value is similar to that of NGC 1399, NGC 1404, NGC 720, and NGC 5044. This result indicates that common metal production process has taken place.

4.3. Metal-mass-to-light-ratio (MLR)

O and Fe radial mass distributions are similar between NGC 4636 and NGC 1399. This indicates that both objects have similar metal diffusion process. In addition, the MLR of NGC 4636 is 2∼3 times larger than that of NGC 1399, possibly due to that NGC 4636 confines more metal-rich gas. Figure 2 shows IMLR and OMLR at 0.1 r_{180} among several galaxies. There may be a correlation between the temperature and MLR in spherical objects, NGC 4636, NGC 5044 and HCG 62. On the other hand, NGC 1399 and NGC 507 show a relatively low MLR. This indicates that they experience galaxy interaction frequently and metal rich gas could be stirred by galaxy motions.

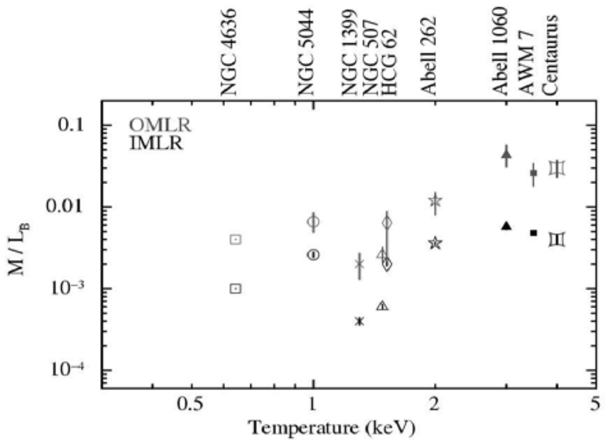

Fig. 2. IMLR and OMLR at $0.1r_{180}$ using B band luminosity.

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