Suzaku observation of O and Ne abundances in interstellar medium of S0 galaxy, NGC 4382

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Abstract

We derived O and Ne abundances in the interstellar medium (ISM) of a relatively isolated S0 galaxy, NGC 4382, observed with the Suzaku XIS instrument, and compared the abundance pattern of O/Ne/Mg/Fe to those of ISM in elliptical galaxies. The O/Fe ratio is a factor of 2 smaller than those of ISM in elliptical galaxies, NGC 720, NGC 1399, NGC 1404 and NGC 4636, observed with Suzaku. Since O, Ne, Mg are predominantly synthesized by supernovae (SNe) II, the observed abundance pattern indicates that the contribution of SN Ia products is higher in the S0 galaxy, than those in elliptical galaxies. Our result supports that spiral galaxies have changed into S0 galaxies, since stars in spiral galaxies thought to contain more SN Ia products than those in ellipticals.

Key words: galaxies: individual (NGC 4382), galaxies: ISM, galaxies: abundances, X-rays: ISM

1. Introduction

The early-type galaxies have a hot, X-ray emitting interstellar medium (ISM), which is considered to be gravitationally confined (e.g., Mathews et al. 2003). For understanding the metal enrichment processes, the Suzaku satellite is a powerful tool, due to its better energy resolution and lower background than any previous X-ray CCD detector (Koyama et al. 2007).

The optical observations show no statistically significant evidence of fractions of elliptical, S0 and spiral galaxies in clusters at the redshift z>0.5. In contrast, the lower redshift clusters z<0.5 have increases in the fractions of S0 galaxies, accompanied by a commensurate decrease in that of spiral galaxies and no evolutions in the elliptical fractions (e.g., Desai et al. 2007). These seem to suggest that spiral galaxies changed into S0 galaxies at z< 0.5, falling into clusters of galaxies.

Optical observations indicates that the [Mg/Fe] ratio is super-solar in the cores of bright elliptical galaxies (e.g. Thomas et al. 2005). This overabundance of Mg relative to Fe is the key indicator that galaxy formation occurred before a substantial number of SNe Ia could explode and contribute to lower the [Mg/Fe] ratio (e.g. Pipino et al. 2009).

With Suzaku, the abundance pattern of ISM of elliptical galaxies, NGC 720 (Tawara et al. 2008), NGC 1399, NGC 1404 (Matsushita et al. 2007) and NGC 4636 (Hayashi et al. 2009) were reported. In this paper, we first investigated stellar metallicity of a S0 galaxy, NGC 4382.

Throughout this paper, we adopt the new solar abundance table by Lodders (2003). Errors are quoted at 90% confidence.

2. Targets and Observation

NGC 4382 is a S0 galaxy located in the outskirt of Virgo cluster, 1.7 Mpc from cD galaxy M87. NGC 4382 is relatively isolated, and suitable to investigate the heavy element of the ISM of galaxy itself.

The Suzaku observation of the NGC 4382 was carried out on June 2008 with an exposure of 99 ksec.

3. Analysis

We extracted the spectra within 4 r_e circular region and outside 5 r_e to estimate the background, centered on the optical center of NGC 4382. Here, r_e is the effective radius of a galaxy.

Then, we fitted the spectra subtracted Non-X-ray background within 4 r_e and outside of 5 r_e, for CXB and Galactic components, with the vAPEC model for ISM, two power-law models for unresolved sources and CXB, and two APEC models for Galactic emission. Here, we assumed that the CXB and Galactic emissions in the region within 4 r_e have the same surface brightness and spectral parameters as those of outside of 5 r_e.

4. Results

The derived ISM temperature within 4 r_e is about $0.31^{+0.02}_{-0.02}$ keV. This temperature is lower than those of the early-type galaxies which has been observed with

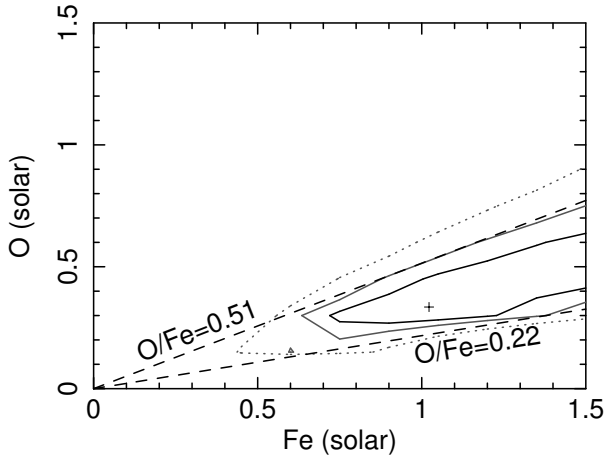

Fig. 1. Confidence contours of the O abundance and Fe abundance. The cross mark denotes the best-fit location, and the contours represent 68%, 90% and 99% confidence level, respectively. Dashed lines correspond to O/Fe=constant.

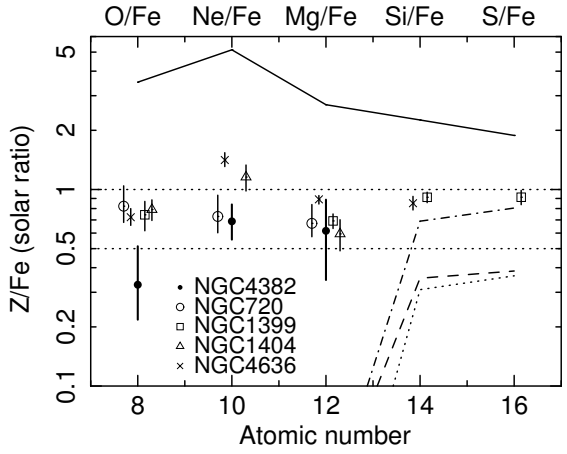

Fig. 2. Abundance ratios of O, Ne, and Mg against Fe from the single-temperature model fit. For comparison, we plotted abundance ratios of elliptical galaxies, NGC 720, NGC 4636, Fornax cD, and NGC 1404 are plotted. Solid line represents the ratio of metals to Fe produced from SN II, and dotted or dashed lines are represent from SN Ia.

Suzaku, NGC 720, NGC 1399, NGC 1404 and NGC 4636 (Matsushita et al. 2007; Tawara et al. 2008; Hayashi et al. 2009).

The Fe abundance of the ISM is ~ 0.6–2.9 solar. This value of Fe abundance is consistent with that of other early-type galaxies, NGC 720, NGC 1399, NGC 1404 and NGC 4636.

We derived the metal-to-Fe ratios, O/Fe, Ne/Fe and Mg/Fe, from confidence contours (Figure 1). We can well constrained the abundance ratios. The abundance ratios of O/Fe, Ne/Fe and Mg/Fe are $0.33^{+0.19}_{-0.11}$, $0.69^{+0.15}_{-0.13}$ and $0.62^{+0.27}_{-0.27}$ in solar units, respectively. The O abundance are especially smaller than the Fe abundance in units of solar abundance.

5. Discussion

5.1. Comparison with the abundance ratio of ISM in elliptical galaxies

Figure 2 compares the abundance pattern of NGC 4382 with those of other elliptical galaxies, NGC 720 (Tawara et al. 2008), NGC 1399, NGC 1404 (Matsushita et al. 2007) and NGC 4636 (Hayashi et al. 2009).

The abundance ratios of elliptical galaxies have similar pattern with a small scatter, except Ne/Fe ratios, and not so different from the solar abundance by Lodders (2003). The average ratios of O/Fe, Ne/Fe and Mg/Fe of these 4 elliptical galaxies are 0.77, 1.10 and 0.71 in solar units, respectively. As shown in Figure 2, the O/Fe ratio of NGC 4382 is a factor of 2 smaller than those of elliptical galaxies. While, the Ne/Fe and the Mg/Fe ratios of NGC 4382 tend to be smaller. These results suggest the differences of metal enrichment history of ISM between NGC 4382 and elliptical galaxies.

5.2. Contributions from SN Ia and SN II

The theoretical SN Ia and SN II yields are also plotted in Figure 2. Here, we refer the SN Ia and II yields calculated by Iwamoto et al. (1999) and Nomoto et al. (2006), respectively.

The ISM abundance ratios of NGC 4382 and elliptical galaxies are located between those of SN Ia and SN II. This suggests that these abundances are the mixture of the yields of SN Ia and SN II.

Since the O is not synthesized by SNe Ia, observed lower O/Fe ratio of the ISM in NGC 4382 indicates a larger contributions from SN Ia in this S0 galaxy than those of elliptical galaxies. In order to explain the result, present SN Ia rate between S0 and elliptical galaxies are different, or stars in S0 galaxies contain more SN Ia products than those of elliptical galaxies.

Higher SN Ia products in stars suggest that spiral galaxies changed to S0 galaxies, considering that stars in spiral galaxies contains more SN Ia products than giant elliptical galaxies.

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