Suzaku Observation of the Supernova Remnant G344.7−0.1

Shigeo Yamauchi

Department of Physics, Faculty of Science, Nara Women's University
E-mail(SY): yamauchi@cc.nara-wu.ac.jp

Abstract

Suzaku observed the supernova remnant G344.7−0.1. An extended X-ray emission with a diameter of 6′–8′ was clearly found. In addition to emission lines from highly ionized Si, S, Ar, and Ca, the X-ray spectrum exhibited a strong emission line at an energy of 6.465 keV from low-ionized Fe. The Fe K-line was represented by a broad Gaussian line model. The overall spectra in the 1–10 keV band were well represented by a two-component non-equilibrium ionization model. The results of a spectral fitting indicate that Si, S, Ca, and Fe are overabundant relative to the solar values.

Key words: ISM: supernova remnants — X-rays: ISM — X-rays: spectra

1. Introduction

Supernova and supernova remnants (SNRs) are very important objects, because they are the main site of heavy element production in galaxies. X-ray observations are useful for performing plasma diagnostics. However, since X-rays in the low-energy band are absorbed by the interstellar medium and there are many bright X-ray sources containing a compact object, our knowledge of the X-ray properties of faint (distant) SNRs is still limited.

G344.7−0.1 is an SNR with a size of 8′–10′ (Green 2009, references therein). Based on the radio flux density and the Σ-D relation, a diameter and a distance to G344.7−0.1 are estimated to be ∼33 pc and ∼14 kpc, respectively (Dubner et al. 1993). The large size suggests that G344.7−0.1 is a middle-aged SNR.

X-ray emission from G344.7−0.1 was discovered in the ASCA Galactic plane survey for the first time (Yamauchi et al. 1998, 2005). The X-ray emission with a diameter of 6′–8′ coincides with the bright western part in the radio band image. The spectral fitting revealed the metal enhancement and the existence of a strong low-ionized Fe K-line (∼6.4 keV) even in the middle-aged SNR (Yamauchi et al. 2005), and hence G344.7−0.1 is an unique SNR.

In order to study the X-ray emitting plasma of G344.7−0.1 in detail, we observed G344.7−0.1 with the Suzaku satellite (Mitsuda et al. 2007). In this paper, the results are presented.

2. Observations and Results

The Suzaku observation of G344.7−0.1 was carried out with X-ray CCD cameras (XIS) on 2007 February 21–22. The exposure time after data screening was 42.1 ks.

Figure 1 shows an X-ray image obtained in the 1–10 keV energy band overlaid with the radio band image (843 MHz, Whiteoak & Green 1996). An extended X-ray emission with a diameter of 6′–8′ was clearly found. The X-ray image is consistent with that of the ASCA results (Yamauchi et al. 2005).

Figure 2 shows X-ray spectra extracted from a region with a radius of 4′.2 from the center of the extended X-ray emission. The background counts extracted from an annular region between 4′.2 and 6′.8 were subtracted. The spectra exhibited several emission line features. Based on results of a spectral fitting with a bremsstrahlung and Gaussian line model, these lines were identified with K-lines from Si, S, Ar, Ca, and Fe. The line energies of Mg, Si, S, Ar, and Ca K-lines are consistent with those expected in the thin hot plasma with a temperature of ∼1 keV, but that of a Fe K-line (E=6.465 keV) is significantly lower than ∼6.7 keV expected in the hot plasma. Moreover, emission lines from Mg, Si, S, Ar, and Ca are narrow, but only the Fe line is represented by a broad Gaussian line model. These indicate that the X-ray spectra cannot be represented by a single component model and another emission component with a strong emission line from Fe is required.

Both the line energy and the line width are consistent with those expected from Fe ions in a hot plasma in non-equilibrium ionization (NEI) state with an ionization time scale of $\sim10^{10}$ cm^{-3} s and a temperature of several keV. Therefore, the X-ray spectra were fitted with a two-component NEI model (vnei model in XSPEC). The used NEI model (vnei version 1.1) did not reproduce line features at ∼1.6 keV and ∼3.1 keV. To reproduce the line features, two narrow emission lines were added at ∼1.6 keV and ∼3.1 keV. Since the temperature of the hard component, $kT_{\rm hard}$, could not be constrained

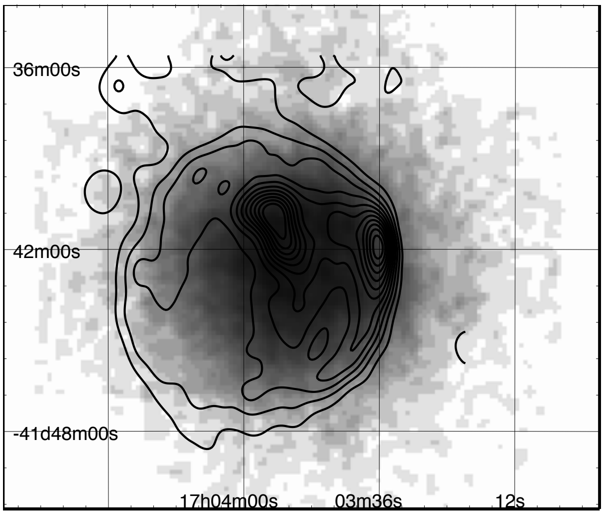

Fig. 1. X-ray image obtained in the 1–10 keV energy band (gray scale). The background subtraction and the vignetting correction are not made. The contour shows the radio intensity map (843 MHz: Whiteoak & Green 1996).

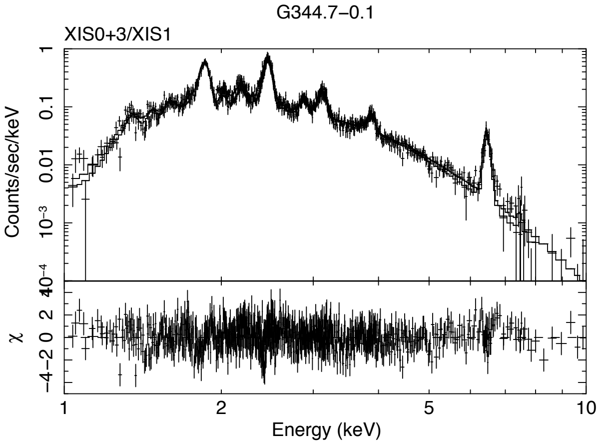

Fig. 2. XIS spectra obtained in the 1–10 keV energy band. The crosses and the histogram in the upper panel show the spectral data and the best-fit two-component NEI model, respectively. The lower panel shows the residuals from the best-fit model.

well, $kT_{\rm hard}$ was assumed to be 5 keV. The abundance tables were taken from Anders & Grevesse (1989), while the cross sections of the photoelectric absorption were taken from Morrison & McCammon (1983). The abundances of Si, S, and Ca for the soft component and Fe for the hard component were free parameters, but those of other elements were fixed to the solar values. The two-component NEI model well represented the overall spectra in the 1–10 keV energy band. The temperature of the soft component is ~1 keV, while the ionization timescales of the soft and the hard components are $\sim 2 \times 10^{11}$ cm^{-3} s and $\sim 1 \times 10^{10}$ cm^{-3} s, respectively. The abundances of Si, S, and Ca of the soft component (the 1 keV plasma) are larger than the solar values (1.6–3.0 solar), while the Fe in the hard component is also significantly overabundant (~20 solar).

3. Discussion

A diameter of G344.7−0.1 is estimated to be ~33 pc (Dubner et al. 1993), while the plasma temperature of the soft component derived from the present analysis is lower than those of young SNRs such as Tycho's SNR and Kepler's SNR (kT=2–4 keV, e.g., Hwang & Gotthelf 1997, Kinugasa & Tsunemi 1999), but is consistent with those of middle-aged SNRs. In the case of middle-aged SNRs, the X-ray emitting matter mainly consists of an ambient matter. Thus, the overabundance derived from the Suzaku observation suggests that G344.7−0.1 appeared in a locally metal-enhanced region.

The obtained energy of the Fe K-line is significantly higher than that of neutral Fe (6.4 keV) and the Fe line is represented by a broad Gaussian line model. These results indicate that a scenario of a fluorescence line from cold matter is unlikely. A scenario that a shell of a Fe-emitting plasma is expanding is also unlikely. In the expanding shell scenario, the line width in the central portion is expected to be larger than that in the outer region. However, the line widths are very similar. The broad Fe line is reproduced by the NEI model with an ionization time scale of ~10^{10} cm^{-3} s and the two-component NEI model represents the overall spectra well, which suggests that a scenario of a Fe-rich low-ionized plasma is likely.

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