Suzaku Observation of the Supernova Remnant N23 in the Large Magellanic Cloud

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Abstract

The X-ray emission from the supernova remnant N23 are studied using the X-ray Imaging Spectrometer (XIS) onboard Suzaku. Owing to superior energy resolution of the XIS, we obtained a H-like and He-like Kα emission line spectrum of Oxygen with unprecedentedly high quality. As a result, we identified a new thin thermal spectra component which can be represented with Non-Equilibrium Ionization model with a temperature $\sim$0.2 keV, as well as that with a temperature of $\sim$0.5 keV so far as known. This alters the estimate of the ionization timescale $n_e t$ from $\sim 10^{11}\,\mathrm{cm}^{-3}$ s to $\sim 10^{13}\,\mathrm{cm}^{-3}$s, thereby identifying N23 as an old SNR, rather than a young SNR($\sim$3800 yr) as believed so far.

Key words: supernova remnants, X-ray

1. Introduction

Chemical evolution of the universe has been one of the major issues in the modern astronomy. Heavy elements, or metals, have been generated and accumulated in the universe since its begining mainly through supernova explosions. In X-ray observations, we can obtain information on parameters on the optically thin thermal plasma which include plasma temperatures, metal abundance, kinematic energy, ionization ages, and so on. These pieces of information will lead us to understand galactic chemical evolution and star formation history. A systematic study of supernova remnant in the Large Magellanic Cloud (LMC) suits well for this purpose, because of its well-known distance of 50 kpc, small interstellar absorption to LMC. N23 is one of the SNRs in the LMC. It is classified by its morphology as a middle-aged ($\sim$3800 yr) and an irregular-shaped SNR in Huges et al. 1998.

2. Observation and Data Reduction

The *Suzaku* XIS image of N23 (South) and DEM L71 (North) below 2 keV are shown in Fig.1 N23 is extended with $\sim$45"×90". Data reduction and analysis of the present data were carried out using the HEADAS software package version 6.5.1. The data processed by *Suzaku* pipeline processing software (ver 2.0) were analyzed. In Screening the data, we removed time intervals while the elevation angle from the night earth is less than 5°. We discarded the data while the spacecraft passes through the South Atlantic Anomaly and the cut-off rigidity is less than 6GV/c. In the standard data screening procedure, the time inversals during which the elevation angle from the day earth is less than 20° are discarded. These result in, however only $\sim$5.6 ksec data available. We thus reduce the day-earth elevation angle by degrees by closely comparing resulting spectra and have finally found that the solar X-ray contamination dose not raise any spectral modification even if we reduce the day earth elevation down to 5° (DYE_ELV> 5°) for XIS data. Owing to this study, the total exposure time has increased to 7.5 ksec.

3. Spectral Analysis

In spectral analysis, we use xspec version 11.3.2aj for spectral fitting. The XIS response matrix (RMF) and auxiliary response file (ARF) are calculated using xisrmfgen (version 2007-05-14) and xissimarfgen (version 2008-04-05), respectively. In evaluating the spectrum of N23 through spectral fitting, we begin with a single component vnei model attenuated by photoelectric absorption due to the interstellar matter in our galaxy and LMC, whose thickness is represented by the hydrogen column densities $N_{\mathrm{H}}^{\mathrm{G}}$ and $N_{\mathrm{H}}^{\mathrm{L}}$, respectively. We have fixed $N_{\mathrm{H}}^{\mathrm{G}}$ at the value of our galaxy in the direction to N23 $1.98\times10^{21}\mathrm{cm}^{-2}$, whereas $N_{\mathrm{H}}^{\mathrm{L}}$ is set free to vary. The result is summarize in the second column of table 1 labelled '$1kT1nt$'. Since the carbon abundance cannot be constrained because of the large interstellar absorption at carbon Kα line energies, we fixed it to the LMC value (Russell & Dopita 1992). In the course of the fitting, we noticed that the central energies of hydrogenic and He-like Kα lines from O, Ne, and Mg show discrepancies between the model and the data. We therefore allowed energy offset to be floated. As a result, the energy offset is converged to -11eV and -2eV, for the FI and BI spectra, respectively. The temperature and the inonization timescale are consistent to the *ASCA* measurement, which are $kT_e = 0.53 \pm 0.10$ keV and $\log(n_e t) = 10.9 \pm 0.3\mathrm{cm}^{-3}\mathrm{s}$ (Huges et al. 1998). As noticed from this table, however the single component vnei model no longer provides an acceptable fit ($\chi^2_\nu = 2.1$). We thus decided to append another vnei model. To reduce the number of model parameters as much as possible, however, we constrained either kT_e or $n_e t$ common between the two vnei component, and fit them to the data separately. The improvement of the $2kT1nt$ model is more remarkable, and it provides an acceptable fit at the 90% confidence level. The result of the fit is shown graphically in Fig2. This result indicates that there exists indeed another optically thin thermal plasma component with a temperature of ~0.2 keV, in addition to the 0.5–0.6keV component so far known. It is very important to note that the best-fit value of the ionization timescale now becomes $\log(n_e t) > 10^{13}$ $\mathrm{cm}^{-3}\mathrm{s}$, which alters the age estimation of N23 larger by a few orders of magnitude. N23 should now be regarded as an old SNR, rather than a young SNR as considered so far based on the single vnei model.

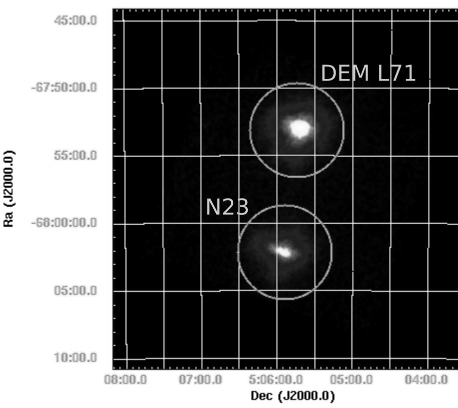

Fig. 1. Suzaku XIS X-ray images of the N23 and the DEM L71 in the bands 0.2–2 keV. The images from all the four XIS modules are combined. The circles with a radius of 3. 3 is integration regions of the source photons from N23. The background photons were extracted a source free region. The calibration sources at the corners are masked.

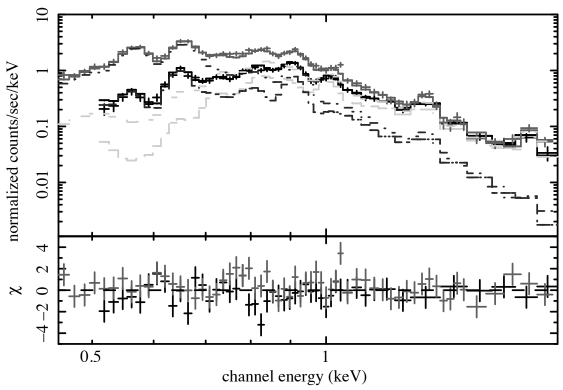

Fig. 2. The data and the best-fit '$2kT1nt$' model of N23. In the 0.45–2.0keV band. The crosseses show the data points from the FI and BI CCDs, respectively. The solid line histograms with same colow are best-fit model. The blue and green broken histograms show the components with kT_e=0.55 and 0.21keV, respectively. The lower panels show the residual of the fit.

4. Discussion

We obtained the H-like and He-like Oxygen emission line spectrum with unprecedentedly high quality, thereby discover a new NEI emission component with a temperature $\sim$ 0.2 keV, in addition to the 0.5 keV component known so far. This alters the estimation of the ionization timescale $n_e t$ significantly, from $10^{10}\mathrm{cm}^{-3}\mathrm{s}$ to $10^{13}\mathrm{cm}^{-3}\mathrm{s}$, and N23 is found to be an old SNR, not a young SNR as believed so far. Our observation on N23 throws out a caveat that similar oversight of the low temperature component may have taken place in other SNRs.

Table 1. Best-Fit Parameter for N23

Parameter	$1kT, 1nt$	$2kT, 1nt$
N_{H}^{G}	0.198(fix)	0.198 (fix)
$N_{\mathrm{H^L}}$	$9.2^{+1.2}_{-0.8}$	$< 1.0 \times 10^{-2}$
kT_1	$0.54^{+0.6}_{-0.3}$	$0.56^{+0.1}_{-0.3}$
kT_2	-	$0.208^{+0.02}_{-0.04}$
$\log(n_e t)$	$10.39^{+0.09}_{-0.05}$	$13.68^{+0.02}_{-0.32}$
$Norm_1$	$1.9^{+1.0}_{-1.0} \times 10^{-2}$	$7.2^{+1.7}_{-0.5} \times 10^{-3}$
$Norm_2$	-	$3.3^{+0.1}_{-0.4} \times 10^{-2}$
C	0.51(fix)	0.51(fix)
N	$< 6.4 \times 10^{-2}$	$0.33^{+0.27}_{-0.12}$
O	$0.21^{+0.06}_{-0.01}$	$0.45^{+0.04}_{-0.12}$
Ne	$0.23^{+0.01}_{-0.02}$	$0.61^{+0.05}_{-0.14}$
Mg	0.19 ± 0.03	$0.50^{+0.08}_{-0.10}$
Si	$0.38^{+0.07}_{-1.4}$	$0.55^{+0.13}_{-0.14}$
Fe	$0.19^{+0.04}_{-0.01}$	$0.38^{+0.02}_{-0.11}$
$\chi^2_\nu(dof)$	2.09(99)	1.08(97)
offset FI (eV)	-11	-8.9
offset BI (eV)	-2	-1.0

References

Hughes et al. 1998 ApJ., 505, 732
Russell & Dopita 1992 ApJ., 384, 508