Line-of-sight spatial extent of warm-hot medium in the direction of PKS 2155-304

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Abstract

We studied the hot gas in the Galactic halo in the direction of a blazer PKS 2155-304 (z =0.117). This is the second direction for combined analysis using high resolution X-ray absorption/emission data. Absorption features of Ovii and Oviii are measured with Chandra LETGS. Suzaku observations of the vicinity of PKS 2155-304 allows us to study emission lines (Ovii, Oviii, Nvii and Neix). We performed a joint analysis of emission and absorption data assuming a vertically exponential galactic disk. The gas temperature and density at the Galactic plane are determined to be $3.2(+0.7, -0.6) \times 10^6$ K and $1.3(+0.4, -0.6) \times 10^{-3}$ cm^{-3} and the scale heights of the gas temperature and density $2.2(+4.4, -2.1)$ kpc and $5.1(+3.9, -4.7)$ kpc, respectively.

Key words: Galaxy: halo — ISM: structure

1. Introduction

The sky is uniformly bright in 0.4–1.0 keV energy band. Emission from the AGNs can only explain about half of this emission. A microcalorimeter experiment (McCammon et al. 2002) revealed that the origin of the remaining emission is thin thermal hot plasmas (T$\sim 10^6$K).

Ovii and Oviii ions are powerful probe to constrain physical parameters of these hot plasmas because ionization fraction and emissivity is very sensitive to temperature. By combining absorption and emission of these lines, we could even measure the density distribution in the sight line direction, since absorption depth depends on integration of the density, while emission intensity integration depends on square of the density.

The first joint analysis of the absorption lines obtained by Chandra LETGS and emission lines by Suzaku XIS was performed toward LMC X-3. This gave us an important clue to the density, temperature and scale heights of the plasma (Yao et al. 2009). With a vertically-exponential galactic disk assumption, the gas temperature and density at the Galactic plane are estimated to be 3.6×10^6 K and 1.4×10^{-3} cm^{-3} and the scale heights of the gas temperature and density are estimated to be 1.4 kpc and 2.8 kpc, respectively. However, since the distance to LMC X-3 is only 50 kpc, the results also depend on another assumption of no emission coming behind.

2. Absorption Analysis

We selected PKS 2155-304 as our target because it was observed by Chandra many times and thus good statistics was obtained. We fitted the LETGS data with models consisting of neutral hydrogen absorption, PKS 2155-304 emission and Ovii Kα, Oviii Kα and Ovii Kβ absorption lines. Line broadening due to the velocity dispersion (V_b) is calculated in the model. Broad Oviii Kα line indicates that velocity dispersion is large. Fitting results are shown in table 1.

3. Emission Analysis

We observed two vicinities of PKS 2155-304 with Suzaku. We used XIS1 data. After standard GTI selection, we excluded time intervals contaminated by X-ray emissions due to geo-coronal solar wind charge exchange (SWCX) or by fluorescence emissions from sun-lit Earth's atmosphere. We obtained two $\sim$50 ks net exposures.

We fitted Suzaku data with models consisting of neutral hydrogen absorption, superposition of extragalactic AGN emission (CXB), thermal emission from galactic hot plasma and emission from SWCX and local hot bubble (LHB). We fitted emission data of the two observations linking all parameters but normalization of the power-law. The resultant temperature ($\sim$0.2 keV), emission measure and abundance are typical values of

Table 1. The results of Absorption and Emission analysis

Data	log T [a]	Emission Measure [b]	log NH [c]	V_b [d]	Ne/O	Fe/O
Absorption	$6.28^{+0.02}_{-0.02}$	-	$19.08^{+0.06}_{-0.07}$	290^{+152}_{-220}	-	-
Emission	$6.33^{+0.02}_{-0.02}$	$0.003^{+0.0003}_{-0.0003}$	-	-	$3.3^{+1.2}_{-0.9}$	$1.7^{+1.2}_{-0.7}$

[a] in units of log K, [b] in units of cm^{-6} pc, [c] in units of log cm^{-2}, [d] in units of km s^{-1}

Table 2. The results of Combined analysis

Direction	log NH [a]	h_n [b]	log T_0 [c]	γ	Ne/O	Fe/O
PKS 2155-304	$19.41^{+0.18}_{-0.20}$	$5.1^{+3.9}_{-4.7}$	$6.51^{+0.08}_{-0.10}$	$0.43^{+1.15}_{-0.23}$	$2.3^{+1.6}_{-0.5}$	$1.0^{+0.8}_{-0.5}$
LMC X-3	$19.36^{+0.22}_{-0.21}$	$2.8^{+3.6}_{-1.8}$	$6.56^{+0.11}_{-0.10}$	$0.5^{+1.2}_{-0.4}$	$1.7^{+0.6}_{-0.4}$	$0.9^{+0.2}_{-0.2}$

[a] in units of log cm^{-2}, [b] in units of kpc, [c] in units of K

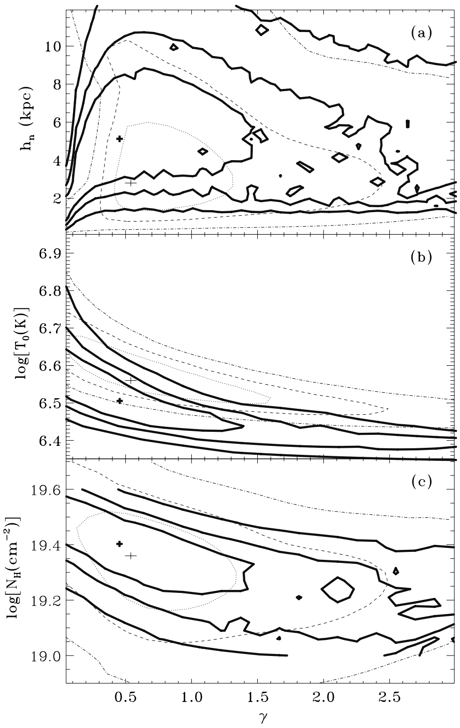

Fig. 1. 68%, 90% and 99% confidence contours of h_n, T_0 and N_H vs. γ, obtained in a joint fit to the X-ray absorption and emission data. Thick lines are from PKS 2155-304 data and thin lines are from LMC X-3 data.

the galactic hot plasma (Yoshino et al. 2009). Fitting results are shown in table 1.

4. Combined Analysis using Exponential Model

The density and temperature distribution of the hot gas toward PKS 2155-304 was studied by a combined analysis of absorption and emission lines of OVII and OVIII . We assumed that the distribution of hydrogen density and temperature is an exponentially decaying function of vertical distance from galactic plane z, since some observations toward edge-on galaxies indicate the distribution. It can be characterized as

$$n = n_0 e^{-z/h_n \xi}, T = T_0 e^{-z/h_T \xi}, \gamma = h_T/h_n, \qquad (1)$$

where n_0 and T_0 are the midplane density and temperature, respectively, and h_n and h_T are the scale heights, and ξ is the volume filling factor that is assumed to be 1 in this work. We also assumed a plane-parallel configuration. By fitting the spectra with this model, T_0, column density and scale heights are determined so that the model represents both absorption and emission spectra. Note that the emission measure is calculated by the column density and density scale height.

Fitting results are summarized in table 2 and confidence contours are shown in figure 1. For comparison, results of LMC X-3 direction are also shown.

The midplane temperature and density (T_0=3.2×10^6 K; n_0= 1.3×10^{-3} cm^{-3}) are typical values of those in the galactic plane.

5. Discussion

We compared the results with that of LMC X-3(table 2). LMC X-3 is located at 50 kpc away, while PKS 2155-304 is an extragalactic object. If the hot gas around our Galaxy extends beyond LMC X-3, the results would show a significant difference. However, they show good consistency. This suggests that the hot halo is confined in ∼ 10 kpc region around our galaxy.

Directions of the LMC X-3 and PKS 2155-304 are (273.6,-32.1) and (17.7,-52.2) in galactic coordinate respectively. The fact that we obtained similar values for the two directions indicate that the hot halo is isotropic in a big picture and can be explained with the exponential model. The density, the scale height and temperature of the hot gas are $\sim 2 \times 10^{19}$ cm^{-2}, a few kpc and $\sim 2 \times 10^6$ K, respectively.

References

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