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Energy Spectra of the Soft X-ray Diffuse Emission in Fourteen Fields Observed with Suzaku

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Abstract

The soft diffuse X-ray emission of twelve fields observed with Suzaku are presented together with two additional fields from previous analyses. All have galactic longitudes $65^\circ < l < 295^\circ$ to avoid contributions from the very bright diffuse source that extends at least $30^\circ$ from the Galactic center. The surface brightnesses of the Suzaku nine fields for which apparently uncontaminated ROSAT All Sky Survey (RASS) were available were statistically consistent with the RASS values, with an upper limit for differences of $17 \times 10^{-6}$ c s$^{-1}$ amu$^{-1}$ in R45-band. The Ovii and Oviii intensities are well correlated to each other, and Ovii emission shows an intensity floor at $\sim 2$ photons s$^{-1}$ cm$^{-2}$ sr$^{-1}$ (LU). The high-latitude Ovii emission shows a tight correlation with excess of Ovii above the floor, with $(\text{Ovii intensity}) = 0.5 \times [(\text{Ovii intensity}) - 2 \text{ LU}]$, suggesting that temperatures averaged over different line-of-sight show a narrow distribution around $0.2$ keV. We consider that the offset intensity of Ovii arises from the Heliospheric solar wind charge exchange and perhaps from the local hot bubble, and that the excess Ovii (2-7 LU) is emission from more distant parts of the Galaxy. The total bolometric luminosity of this galactic emission is estimated to be $4 \times 10^{39}$ erg s$^{-1}$, and its characteristic temperature may be related to the virial temperature of the Galaxy.

Key words: Galaxy: disk — Galaxy: halo — X-rays: diffuse background — X-rays: ISM

1. Introduction

The soft X-ray diffuse background below 1 keV is considered to consist of the contribution of faint extragalactic sources and emissions from highly ionized ions, such as Cvi, Ovii, Oviii, Fe xvii, and Neix, in solar neighborhoods and in our Galaxy. The extragalactic contribution, which we refer to as the Cosmic X-ray Background (CXB) in this paper, is estimated to be about 40% of emission in the so-called ROSAT R45 band (McCammon et al. 2002), which is approximately $\sim 0.44 - 1$ keV. The emission from highly ionized ions is considered to arise from at least three different origins. Among them, the solar wind charge exchange (SWCX) induced emission from the Heliosphere (Cox 1998; Cravens 2000; Lallement 2004), and the thermal emission from the hot gas in local hot bubble (LHB) (McCammon & Sanders 1990) are hard to be separated from each other using emission spectra above $\sim 0.4$ keV. In this energy range, the sum of the two emission components are approximated by a thin-thermal emission of $kT \sim 0.1$ keV without absorption (Smith et al. 2007; Henley et al. 2007; Galeazzi et al. 2007; Kuntz & Snowden 2008; Masui et al. 2009). The remaining emission is considered to arise from more distant part of the galaxy; mostly above or beyond the bulk of absorption in the Galactic disk. Kuntz & Snowden (2000) called this component the “transabsorption” emission (TAE) and separated it in the ROSAT all sky map utilizing the directional dependence of the absorption column density. They found that the emission spectrum can be described by a two-temperature thermal emission model of temperatures $kT \sim 0.10$ and 0.25 keV. However, because there is no constraint on distance other than absorption, it is hard to constrain the origins conclusively.

New insight has been obtained from combined analyses of the absorption lines observed in the energy spectra of extragalactic objects and emission lines of the same ion...
the midplane values of 0.31 keV and 1 Galactic midplane can consistently explain the observa-
temperature and density decrease exponentially from the mal. Instead, a thick Galactic hot gaseous disk whose
gas attributed to the T AE component cannot be isother-
Suzaku. The joint spectral fit of the data shows the hot
LMC X-3 observed with the CCD camera (XIS) onboard
mission grating (HETG) onboard Chandra, and the emis-
spectra from the blank fields about 30' away from
2 Y oshino et al. [V ol.
we clearly detected O
b
viii
emission from all the fields, and
O
vii
absorption. They therefore require
In this paper, we concentrate on the XIS1 data which
has much larger effective area below 1 keV than other
XIS sensors because it employs backside illuminated CCD.
Throughout this paper, we quote single parameter errors
at the 90 \% confidence level unless otherwise specified.

2. Observations and data reduction
2.1. Observations and standard data screening

In Table 1, we show the observations we used in this
paper. The analysis results of the seven data sets,
Off Filament (Off-FIL), On Filament (On-FIL), North
Ecliptic Pole 1 (NEP1), MBM 12 off cloud (M12off), LMC
X-3 Vicinity (LX-3), MBM 12 on cloud (M12on), and
Midplane 235 (MP235) have been already published.

The data reduction done by Yao et al. (2009) for
LX-3 is consistent with that shown in this section. Since
Fujimoto et al. (2007) (NEP1) and Smith et al. (2007)
(M12off) used version 0.7 processed data, we re-analyzed
the data from the data reduction. The second observation
of the North Ecliptic Pole direction (NEP2) was made
about a half year after the first NEP observation. The
aim points of the two observations are identical, although
the roll angle was rotated by about 180°.

The two fields at the bottom of Table 1, M12on and
MP235, are special directions compared to other twelve
fields. M12on is towards the molecular cloud MBM12
located at \sim 100 pc with a bright Cataclysmic Variable in
the field of view behind the cloud, and MP235 is in
the galactic plane at $b = 235^\circ$ with a large ($N_H =
9 \times 10^{21}$ cm$^{-2}$) galactic absorption. They therefore require
spectral models different from those of the other fields in
this paper. The spectral results from these two directions
have already been published (Smith et al. 2007; Masui
et al. 2009) and were analyzed in the same manner as
used in this paper, including the geocoronal SWCX re-
moval. We therefore simply adopt their analysis, although
we have updated their fits to M12on with more recent cal-
ibration data. For these two fields we will simply show the
results in tables and figures and will not show the details
of analysis in the text.

In all the observations, the XIS was set to the normal
clocking mode and the data format was either 3 \times
5 or 5 \times 5. The Spaced-raw Charge Injection (SCI) was on
for Low latitude 86-21 (LL21) and Low latitude 97+10
(LL10). We used version 2.0 processed Suzaku data. We
first cleaned the data using the selection criteria: elevation
from sunlit/dark earth rim > 20/5 deg, cut off rigidity >
8 GV. We checked the dependency of the 0.4 - 0.7 keV
counting rate on the Oxygen column density of the sunlit
atmosphere in the line of sight using the MSIS atmosphere
model (see Fujimoto et al. 2007; Smith et al. 2007; Miller
et al. 2008). We found that the counting rate was con-
stant as a function of the column density for the cleaned
data. Thus there is no significant neutral O emission from
Earth atmosphere in the filtered data.

2.2. Removal of Point sources

We then constructed an X-ray image in 0.3 to 2 keV en-
ergy range. We detected point sources in the 17.8 \times
17.8 field of view for all the data sets except for LL10. We
removed a circular region centered at the source position
in the two fields, LH-1 and LL21. The contributions of the two fields, LH-1
and LL21, are respectively 8 and 12 \%. For these fields,
we analyzed the point source spectra and used the mirror
point spread function to determine their residual contribu-
tion in Ovii and Oviii. We extracted sum of point-source
spectra from the circular source regions and performed
model fittings. As the background spectra, we used the
spectra extracted from source-free circular regions whose
distances from the optical axis of the telescope are equiva-
Ient to the source regions, respectively. We estimated the
upper limits of Ovii and Oviii emission intensities of the
source regions with spectral fits, then their contamination
to the SXDB spectra. The upper limit of contamination
was 0.4 LU for Ovii emission for the both fields. It was
0.2 LU and 0.6 LU for Oviii emission for LH-1 and LL10,
respectively. For GB1428+4217 (GB) a point source of an
intensity of $2.6 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ in the energy band
of 0.3 to 1 keV ( $22 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ in 1 to 10 keV) was
detected at the center of the field of view. We re-
moved a circular region of a 5 arc minute radius for this
observation. The contribution of the source in the counting
rate of the remaining region is estimated to be only
0.2 \%.
2.3. Removal of geocoronal SWCX

The spectrum below 1 keV could be contaminated by the SWCX induced emission from the geocorona (e.g. Cravens et al. 2001). Fujimoto et al. (2007) reported a flare-like increase of X-ray flux during the Suzaku observation of NEP1, which was clearly visible in the light curve of 256 s time bins. In all other observations, the increase is too small to be recognized in the light curve of 256 or 512 s time bins, but still it could be statistically significant in the X-ray spectra when they are integrated over a certain amount of time (e.g. \( \gtrsim 30 \) ks). Thus as the last stage of the data reduction, we removed time intervals in which the data can be contaminated by the SWCX from the geocorona.

We consider two parameters which are related to Suzaku’s geocoronal SWCX intensity. The first one is the solar wind proton flux near the Earth. We calculated the solar-wind proton flux at the Earth using ACE SWEPAM data\(^1\). When the ACE SWEPAM data are not available, we used WIND SWE data\(^2\) or OMNI data from CDAWeb (Coordinated Data Analysis Web)\(^3\).

The second parameter is the Earth-center to magnetopause (ETM) distance, where the magnetopause is defined as the lowest position along the sight line of Suzaku where geomagnetic field is open to interplanetary space. The ETM distance is in the range of \( \sim 2 \) to \( \sim 10 \) Earth radii (\( R_E \)), while Suzaku is in a low earth orbit of an about 650 km altitude. Thus it is always looking at the sky through the magnetopause. The probability of a contamination in Suzaku spectra by the SWCX from the geocorona increases if the shortest Earth-center to magnetopause (ETM) distance is \( \lesssim 5 \ R_E \) (Fujimoto et al. 2007). We calculated the ETM distance every 256 s for all the observation periods using the T96 magnetic field model (Tsyganenko & Sitnov 2005)\(^4\). We obtained the interplanetary plasma parameters required for the calculations from the CDAWeb.

When the sun is quiet the solar wind proton flux stays in the range of \((1 - 4) \times 10^8\) protons \(\text{s}^{-1} \text{cm}^{-2}\), and shows slow (times scales of \( \sim 10 \) ks) time variations. On the other hand, during flaring events, it increases and can go up to \((5 - 10) \times 10^9\) protons \(\text{s}^{-1} \text{cm}^{-2}\), and shows fast (\( \lesssim 1 \) ks) time variations.

For the four observations, GB1428+4217 (GB), Lockman hole 1 (LH-1), On Filament (On-FIL) and Low latitude 86-21 (LL21), the proton flux was always below \(4 \times 10^8\) protons \(\text{s}^{-1} \text{cm}^{-2}\). Among them, during GB and On-FIL observations, the proton flux showed slow variation and the data sets can be divided into two subsets of \((1 - 2) \times 10^9\) protons \(\text{s}^{-1} \text{cm}^{-2}\) and \((2 - 3) \times 10^9\) protons \(\text{s}^{-1} \text{cm}^{-2}\) for GB, and of \((2 - 3) \times 10^9\) protons \(\text{s}^{-1} \text{cm}^{-2}\) and \((3 - 4) \times 10^9\) protons \(\text{s}^{-1} \text{cm}^{-2}\) for On-FIL, respectively. Both during the GB and On-FIL observations, the ETM distance varied in 2 to 10 \( R_E \) range. We created spectra for the subsets and performed spectral fits to determine the OVII and OVIII emission intensities. The fitting model used in this analysis will be described in detail in the next section (3.1). We found the difference in the OVII line intensities was less than 2 \( \sigma \) for both fields. This corresponds to 1.7 LU and 1.3 LU for GB and On-FIL, respectively. For OVIII, the difference was within 1 \( \sigma \), which is 0.5 and 0.6 LU for GB and On-FIL, respectively.

Among all other observations, in part of HL-B, HL-B, and LH-2 observations, the proton flux stayed below \(4 \times 10^8\) protons \(\text{s}^{-1} \text{cm}^{-2}\), and showed variations of more than \(1 \times 10^8\) protons \(\text{s}^{-1} \text{cm}^{-2}\) was observed. We thus also subdivided the data sets according to the proton flux. We found that the variations of OVII and OVIII intensities were within 2 \( \sigma \) level for all those data sets. We thus conclude that when the proton flux is \(< 4 \times 10^8\) protons \(\text{s}^{-1} \text{cm}^{-2}\) the contamination of geocoro-

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\(^1\) The data are available at http://www.srl.caltech.edu/ACE/ACS/.

\(^2\) The data are available at http://web.mit.edu/afs/athena/org/s/space/www/wind.html.

\(^3\) The data are available at http://cdaweb.gsfc.nasa.gov/cdaweb/sp_phys/.

\(^4\) "Ecliptic coordinate"
nal SWCX is relatively small, although there still could remain possibility of contamination of \(\sim 1.5\) LU and \(\sim 0.5\) LU levels for O\(\text{vii}\) and O\(\text{viii}\), respectively. We thus decided to use all the data for the four observations, (GB, LH-1, On-FIL), and LL21.

For the seven observations, High latitude B (HL-B), Lockman hole 2 (LH-2), Off Filament (Off-FIL), LMC X-3 Vicinity (LX-3), North Ecliptic Pole (NEP1), the second North Ecliptic Pole observation (NEP2) and Low latitude 97+10 (LL10), the proton flux shows shows flare-like increase and exceeds \(4 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\) in about a half of the observation. We thus subdivided those data into two subsets according to the proton flux, and determined the O\(\text{vii}\) and O\(\text{viii}\) intensities. We found significant (more than 2 \(\sigma\) in O\(\text{vii}\) or O\(\text{viii}\)) difference between the two spectra for four cases: HL-B, LH-2, NEP1 and NEP2. An example of spectral comparisons is shown in Figure 1. For these four data sets, we decided to use only the time intervals in which the proton flux was lower than \(4 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\). These results are consistent with the geocoronal SWCX contamination reported for Suzaku observations of 4U1830-303 vicinities (Mitsuda et al. 2008).

In order to find out why no difference was found in the remaining three observations, we checked the ETM distance of these observations. As already reported in Yao et al. (2009), the ETM distance became as short as \(1.4R_E\) during the LX-3 observation. However, the magnetic field was open to anti-sun direction when the ETM distance was \(< 5R_E\) during which solar-wind particles cannot penetrate. This explains why there was no significant difference between the high and low proton-flux spectra for this data set. We thus decided to adopt all the data for this observation. During the LL10 and Off-FIL observation, the magnetic field was occasionally open to sun side when the ETM distance dropped below \(5R_E\). We decided to simply discard the time intervals with high proton fluxes for these data because we still have enough statistics.

There remain two data sets, High latitude A (HL-A) and MBM12 off cloud (M12off). During the HL-A observation, the proton flux varied in the range of \(3 \times 6 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\) but the time interval exceeding \(4 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\) was short (\(\sim 1/8\) of data). During the M12off observation, it stayed at a level of \(5 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\). Thus for these data sets, we can not compare spectra with low and high proton fluxes. For HL-A, we subdivided the data sets according to the ETM distance and created two energy spectra with ETM distances = \(5 - 10R_E\) and \(> 10R_E\). We found that the two spectra with different ETM distances show no significant difference. Thus we will use data with the ETM distances \(> 5R_E\). There was a small fraction of the data with the ETM distance \(< 5R_E\), which we decided to discard. For M12off, the ETM distance stayed in \(7 - 9R_E\). Thus further subdivision was not possible, and we decided to use all the data.

We tried to exclude time intervals for which contamination of time variable geocoronal SWCX was significant. However we should keep it in mind that there is still uncertainty of contamination by geocoronal SWCX at 1.5 LU and 0.5 LU levels for O\(\text{vii}\) and O\(\text{viii}\), respectively. In addition, the last data set, M12off, could have larger contamination. In Table 2, we summarize the process we applied to remove time intervals which are suspected to be contaminated by the SWCX from the geocorona. We also show the process for M12on and MP235 fields in the table.

2.4. Non X-ray background

The non X-ray background (NXB) spectrum was constructed from the dark Earth database using the standard method in which the cut off rigidity distributions of the on-source and the background data were made identical (Tawa et al. 2008). We found 5 to 10\% discrepancies in the counting rates above 10 keV between the NXB and the observation data, suggesting background uncertainty of this level. We also analyzed front-illuminated CCD data (XIS0, XIS2, and XIS3. but XIS2 was not available after November 9, 2006) to determine the intensity of the Cosmic X-ray Background (CXB) above 2 keV for each
Table 2. Summary of Geocoronal SWCX removal process

| ID  | (1) | (2) | (3) | (4) | (5) | (6) |
|-----|-----|-----|-----|-----|-----|-----|
| 1   | GB  | ✓   |     |     |     |     |
| 2   | HL-B| ✓   |     |     |     |     |
| 3   | LH-2| ✓   |     |     |     |     |
| 4   | LH-1| ✓   |     |     |     |     |
| 5   | Off-FIL| ✓ |     |     |     |     |
| 6   | On-FIL| ✓ |     |     |     |     |
| 7   | HL-A| ✓   |     |     |     |     |
| 8   | M12off | ✓ |     |     |     |     |
| 9   | LX-3| ✓   |     |     |     |     |
| 10  | NEP1| ✓   |     |     |     |     |
| 11  | NEP2| ✓   |     |     |     |     |
| 12  | LL21 | ✓ |     |     |     |     |
| 13  | LL10| ✓   |     |     |     |     |
| R1  | M12on| ✓ |     |     |     |     |
| R2  | MP235| ✓ |     |     |     |     |

(1) The solar wind flux was always \(< 4 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\). All time intervals were adopted.
(2) Excess in the high-solar-wind-flux spectrum. Time intervals with high solar wind flux were discarded.
(3) The geomagnetic field was open to the anti-sun side, when the ETM distance was low (<5R\(_E\)). All time intervals were adopted.
(4) The geomagnetic field was occasionally open to the sun side when the ETM distance was low. Time intervals with high solar wind flux were discarded.
(5) Proton flux stayed in \(3-6 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\). Time intervals with ETM distance <5R\(_E\) were discarded.
(6) Proton flux stayed in \(3-7 \times 10^8\) protons s\(^{-1}\) cm\(^{-2}\). ETM distance was always >10R\(_E\). All time intervals were used.
2.6. Contamination of the optical blocking filter

The degradation of low energy efficiency due to the contamination on the XIS optical blocking filter was included in the arf file. The gradient of the contaminant thickness over the optical blocking filter is also taken into account. Systematic errors in the contaminant thickness are estimated to be about 10 % (The Suzaku Technical Description4, see also Fujimoto et al. (2007) for early data and Yamasaki et al. (2009) for recent data). We performed all the analysis described in the next section not only for the nominal contaminant thicknesses but also assuming 10% thicker and thinner contaminants. Because the contaminant thickness is gradually increasing with time, we created the arf files of 10% thicker or thinner contaminants by shifting the observation dates from the real dates, except for the 10% thicker cases of LL21 and LL10. For the two cases, the +10 % thickness is larger than that of the most recent date in the latest calibration database. We thus added an absorption model in the model spectra to represent the extra contamination. For all data sets, we found that the best-fit parameters changed by small amount when we varied the assumed contamination thickness by ±10 %. Among the parameters, the OVII emission intensity is most sensitive to the contaminant thickness. The OVII emission intensity varied at most by 0.8 LU (LU = photons s$^{-1}$cm$^{-2}$str$^{-1}$), while the statistical errors were 0.5 to 1.5 LU. Thus we will show only the results with nominal contamination thickness.

3. Analysis and results

3.1. Determination of OVII and OVIII emission intensities

In Figure 2, the energy spectra of thirteen data sets are shown, together with the reference data set, M12on. (The spectrum of MP235 is shown in Figure 5). We can clearly see the OVII (∼0.56 keV) emission lines in all of the spectra.

We first fitted the spectra in 0.4-5.0 keV with a model function, consisting of the CXB component represented by a power-law function or broken power-law functions absorbed with Galactic neutral medium, and two thin thermal-emission components which we consider to represent the Heliospheric SWCX induced emission plus the thermal emission from the local hot bubble, and the thermal emission from more distant part of the Galaxy. As the thin thermal emission model, we used APEC (http://hea-www.harvard.edu/APEC/). The first APEC component representing the sum of the SWCX from the Heliosphere and the emission from the local hot bubble (hereafter SWCX+LHB) is unaffected by the Galactic absorption. The contribution of the LHB is considered to be at most one third of this component and could be as small as ∼1/20 (see the discussion by Smith et al. (2007)). The SWCX induced X-ray emission is a non-thermal process. Thus there is no logical reason that the spectrum of this component can be approximated by thermal emission. In particular, fine structure of lines and line intensity ratios of different transitions must be very different from those of thermal emission (e.g. Kharchenko et al. (2003)). However, the spectrum of this component has been successfully represented by thin thermal models. Since Suzaku does not have enough energy resolution to resolve fine structures of lines, and since this component mainly contributes to the Suzaku spectra of the energy range below ∼0.6 keV, the same approximation can be applied to the present data.

Galactic emission beyond the LHB may arise inside the bulk of Galactic absorption. However, we assume that the second thermal component is subject to the total Galactic absorption; i.e. the transabsorption emission (TAE). This assumption is consistent with the discussion in the next subsection (3.2). We fixed the column densities of absorption, N$_{HI}$, for the CXB and the TAE components to the total H column density determined by 21 cm observations (Dickey & Lockman 1990) except for On Filament (On-FIL) and Off Filament (Off-FIL) data. For these two data sets, Henley et al. (2007) and Henley & Shelton (2008) used the column densities estimated from the 100-µm intensity from the all-sky IRAS maps using the conversion relation for the southern Galactic hemisphere by Snowden et al. (2000). We thus tried spectral fits using two different N$_{HI}$ values.

The average AGN spectrum below ∼1 keV becomes steeper than above ∼1 keV, and the average photon index was determined to be 1.96 below ∼1 keV by Hasinger et al. (1996). We thus tried two different models for the CXB: a power-law model with a photon index fixed to 1.4, and a double broken power-law model used by Smith et al. (2007). The latter model consists of two broken power-law functions with photon indices of 1.54 and 1.96 below 1.2 keV and a photon index of 1.4 above the energy. We fixed the normalization of the broken power law component with a low-energy photon index of 1.54 to 5.7 photons s$^{-1}$ keV$^{-1}$ str$^{-1}$ at 1keV and set the normalization of the other broken power-law component free.

First we fixed the elemental abundances of both thin thermal components to the solar value (Anders & Grevesse 1989), and set the temperature and normalization free. We call these models with the double broken power-law CXB model and with the simple power-law CXB model respectively model 1 and model 1’.

In Tables 3 and 4, we summarize the results of the spectral fits. The best fit model functions convolved with the instrument response functions are plotted in Figure 2 for fits with model 1. For HL-B and HL-A with model 1, and for GB and HL-B for model 1’, the temperatures of the two thermal components could not be constrained well because of strong coupling between the two components. In these cases, we fixed the temperature of the SWCX+LHB components to the average values of other spectra. For GB and LH-2 with model 1, the existence of the TAE component was not significant. Thus for these two cases we fixed the temperature of the TAE component to the average value of other spectra other than LL10 (0.264 keV), and estimated the upper limit of the normalization pa-
Fig. 2. Observed spectra (crosses) with NXB subtracted, best-fit model 1 and its components (step functions) convolved with the instrument response function and residuals of the fit (bottom panels). The model function consists of three spectral components, CXB, TAE and SWCX+LHB. The TAE and SWCX+LHB were represented by thin thermal emission model of solar abundance. The CXB component was represented by a double broken power-law model. Thus there are two curves for this component. The vertical error bars of data points correspond to the $1\sigma$ statistical errors. Some of the spectra show a large excess over the model at Ne K emission ($\sim 0.9$ keV). The hard spectral component which is dominant above $\sim 2$ keV for M12on represents the Cataclysmic Variable behind the MBM-12 molecular cloud. The observed spectrum of MP235 is found in Figure 5.
Fig. 2. Continued.
Table 3. Results of three-component (CXB, TAE, SWCX+LHB) spectral fits with the double broken power-law CXB (model 1)

| ID   | \(N_H\)^a | CXB^c | TAE          | SWCX+LHB       | \(\chi^2/\text{dof}\) |
|------|------------|-------|--------------|----------------|------------------------|
| 1 (GB) | 1.40 5.8±0.6 | 0.264±0.007 | <1.7c         | 0.142±0.020 | 6.2±1.4 | 91.25/92 |
| 2 (HL-B) | 3.36 2.7±0.6 | 0.272±0.081 | 1.6±0.8       | 0.120±0.007 | 6.8±1.9 | 94.45/87 |
| 3 (LH-2) | 0.56 3.6±0.5 | 0.264±0.006 | <1.0f         | 0.099±0.027 | 16.3±3.9 | 94.74/99 |
| 4 (LH-1) | 0.56 5.6±0.4 | 0.476±0.279 | 1.3±0.8       | 0.137±0.017 | 8.3±1.4 | 154.08/127 |
| 5 (Off-FIL) | 4.19 3.0±0.5 | 0.271±0.007 | 7.2±1.7       | 0.118±0.006 | 25.5±5.5 | 173.17/122 |
| 6 (Off-FIL) | 1.90 2.9±0.4 | 0.273±0.024 | 5.8±1.4       | 0.122±0.015 | 21.9±4.9 | 169.90/122 |
| 7 (Off-FIL) | 4.61 4.8±0.5 | 0.644±0.581 | 1.9±0.5       | 0.182±0.021 | 7.0±0.7 | 128.57/117 |
| 8 (On-FIL) | 9.60 5.1±0.5 | 0.627±0.072 | 2.7±0.6       | 0.183±0.010 | 8.1±0.6 | 127.35/117 |
| 9 (On-FIL) | 1.02 4.9±0.5 | 0.237±0.033 | 3.5±1.0       | 0.120±0.007 | 10.0±0.4 | 141.01/116 |
| 10 (On-FIL) | 8.74 1.8±0.5 | 0.245±0.118 | 2.4±1.4       | 0.102±0.008 | 21.4±6.5 | 86.27/89 |
| 11 (On-FIL) | 4.67 8.7±0.5 | 0.310±0.087 | 6.0±1.3       | 0.140±0.013 | 9.9±1.9 | 211.71/196 |
| 12 (On-FIL) | 4.40 3.0±0.5 | 0.244±0.023 | 9.5±1.7       | 0.113±0.009 | 23.8±6.3 | 158.44/120 |
| 13 (On-FIL) | 4.40 2.8±0.5 | 0.271±0.040 | 7.7±3.1       | 0.116±0.020 | 18.9±17.3 | 60.85/55 |
| 14 (On-FIL) | 7.24 4.3±0.5 | 0.284±0.035 | 6.8±2.1       | 0.109±0.020 | 24.5±9.6 | 105.03/97 |
| 15 (On-FIL) | 4.00 2.6±0.6 | 0.738±0.214 | 1.5±0.7       | 0.112±0.032 | 8.1±2.6 | 84.28/ 89 |
| R1 Mi2on^g | 40.00 1.7±0.6 | -      | -            | 0.095±0.007 | 18.8±8.9 | 141.62/136 |
| R2 2P235 | 90.00 6.0±1.0 | (0.765±0.039 | 3.73±0.38 )^h | 0.108±0.048 | 12.4±9.4 | 75.80/ 84 |

^a The absorption column densities for the CXB and TAE components were fixed to the tabulated values. They were estimated fromDickey & Lockman (1990), except for 5' and 6', for which the values were estimated from the 100 μm intensity of the direction (Henley & Shelton 2008).

^b Two broken power-law model was adopted. The photon indices below 1.2 keV were fixed to 1.52 and 1.96. The normalization of the former index component is fixed to 5.7 photons s⁻¹ cm⁻² keV⁻¹ str⁻¹ @1 keV.

^c The normalization of the broken power-law component with a photon index of 1.96 below 1.2 keV.

^d The emission measure integrated over the line of sight, \((1/4\pi) \int n_e n_H ds\) in the unit of \(10^{14}\text{cm}^{-5}\text{str}^{-1}\).

^e The TAE component was not significant. The upper limit of the normalization was determined for the average TAE temperature of the TAE component of other observations.

^f Because of the strong coupling between the TAE and LHB+SWCX components, the temperatures of the two components were not well determined. We thus fixed the temperature of the SWCX+LHB component to the average value of other observations.

^g A spectral component for the bright point source represented by an absorbed bremsstrahlung was included in the fits but is not tabulated. The model parameters are \(kT = 200\) keV (fixed), the normalization factor \(= 2.66 \pm 0.14 \times 10^{-12}\) cm⁻³ str⁻¹ (when a point source was replaced with a 20' radius flat emission), and \(N_H = 5.5 \times 10^{22}\) cm⁻² (fixed).

^h This component represents the "narrow bump" component (Masui et al. 2009) rather than the TAE. No absorption was included in this component. This component emits OvIII emissions and the O abundance was set free (the best-fit value is \(3.1^{+1.3}_{-1.4}\) solar.)
Table 4. Results of three-component (CXB, TAE, SWCX+LHB) spectral fits with the power-law CXB model (model 1')

| ID   | NH \(^{a}\) (10\(^{20}\) cm\(^{-2}\)) | CXB\(^{b}\) Norm\(^{c}\) | TAE \(^{d}\) | SWCX + LHB \(^{e}\) | \(\chi^2/\text{dof}\) |
|------|---------------------------------|----------------|----------|-----------------|----------------|
| 1    | 1.40 10.9 ± 0.6                  | 0.203 ± 0.008 | 3.3 ± 1.1 | 0.112 ± 0.08   | 8.1 ± 0.7     | 89.86/91  |
| 2    | 3.36 8.0 ± 0.5                   | 0.273 ± 0.066 | 2.3 ± 1.0 | 0.112 ± 0.06   | 9.5 ± 0.8     | 96.37/87  |
| 3    | 0.56 8.7 ± 0.6                   | 0.335 ± 0.100 | 1.0 ± 0.6 | 0.087 ± 0.03   | 36.4 ± 1.2    | 89.76/97  |
| 4    | 0.56 10.6 ± 0.4                  | 0.354 ± 0.038 | 2.5 ± 0.6 | 0.110 ± 0.02   | 15.2 ± 0.4    | 172.90/127|
| 5    | 4.19 8.2 ± 0.4                   | 0.273 ± 0.019 | 7.9 ± 1.5 | 0.088 ± 0.04   | 28.9 ± 1.0    | 178.04/122|
| 5'   | 1.90 8.2 ± 0.4                   | 0.276 ± 0.012 | 6.5 ± 0.9 | 0.118 ± 0.05   | 25.7 ± 1.2    | 174.37/122|
| 6    | 4.61 10.0 ± 0.5                  | 0.626 ± 0.073 | 2.1 ± 0.5 | 0.182 ± 0.02   | 7.8 ± 0.6     | 124.99/117|
| 6'   | 6.60 10.2 ± 0.5                  | 0.618 ± 0.062 | 3.0 ± 0.6 | 0.183 ± 0.02   | 8.8 ± 0.7     | 131.00/117|
| 7    | 1.02 10.1 ± 0.4                  | 0.242 ± 0.036 | 4.9 ± 1.3 | 0.093 ± 0.04   | 27.8 ± 1.0    | 142.17/115|
| 8    | 8.74 7.2 ± 0.4                   | 0.260 ± 0.071 | 2.7 ± 1.9 | 0.101 ± 0.05   | 23.9 ± 1.0    | 86.99/89  |
| 9    | 4.67 13.4 ± 0.5                  | 0.308 ± 0.023 | 7.6 ± 1.5 | 0.125 ± 0.03   | 14.7 ± 0.3    | 214.27/196|
| 10   | 4.40 8.1 ± 0.4                   | 0.250 ± 0.016 | 9.1 ± 1.8 | 0.112 ± 0.03   | 26.8 ± 1.4    | 171.74/120|
| 11   | 4.40 8.1 ± 0.7                   | 0.275 ± 0.036 | 8.3 ± 1.9 | 0.133 ± 0.04   | 21.8 ± 0.9    | 63.15/55  |
| 12   | 7.24 9.5 ± 0.5                   | 0.287 ± 0.033 | 7.6 ± 1.7 | 0.101 ± 0.01   | 33.5 ± 2.5    | 104.43/97 |
| 13   | 27.10 7.8 ± 0.5                  | 0.721 ± 0.190 | 1.9 ± 0.8 | 0.113 ± 0.05   | 8.0 ± 0.5     | 84.70/89  |
| R1 M12on\(^{f}\) | 40.00 7.2 ± 0.9                  | -              | -         | 0.096 ± 0.04   | 18.5 ± 0.8    | 141.34/136|
| R2 MP235 | 90.00 11.1 ± 0.9                   | (0.766 ± 0.041) | 3.75 ± 0.40 | (0.105 ± 0.005) | 14.1 ± 0.6    | 76.54/84  |

\(^{a}\) The absorption column densities for the CXB and TAE components were fixed to the tabulated values. They were estimated from Dickey & Lockman (1990), except for 5' and 6'. The column densities were estimated from the 100 \(\mu\)m intensity of the direction.

\(^{b}\) A power-law model with a photon index of 1.4 was adopted.

\(^{c}\) The normalization of the power-law function with the unit of photons s\(^{-1}\) cm\(^{-2}\) keV\(^{-1}\) sr\(^{-1}\) at 1 keV.

\(^{d}\) The emission measure integrated over the line of sight, \((1/4\pi) \int n_e n_H d_s\) in the unit of 10\(^{14}\) cm\(^{-5}\) str\(^{-1}\).

\(^{e}\) Because of the strong coupling between the TAE and LHB + SWCX components, the temperatures of the two components were not well determined. We thus fixed the temperature of the SWCX + LHB component to the average values of other observations.

\(^{f}\) The model parameters for the point source were \(kT = 200\) keV(fixed), the normalization factor = \(2.65 \pm 0.14 \times 10^{-12}\) cm\(^{-5}\) str\(^{-1}\) for a 20' radius flat emission, and \(N_H = 5.5 \times 10^{22}\) cm\(^{-2}\) (fixed). See table note (g) of Table 3.

\(^{g}\) "Narrow bump" component. The best-fit O abundance was 3.1\(^{+3.3}_{-1.3}\). See table note (h) of Table 3.

The resultant \(\chi^2\) values were generally good (reduced \(\chi^2\) is 0.95 – 1.42 for 87 – 196 degrees of freedom.) The best-fit values of the temperatures of the two thin-thermal models are contained in a relatively narrow range. They are from 0.10 to 0.14 keV for the LHB + SWCX component and from 0.22 and 0.48 keV for the TAE, except for the TAE temperatures of On-FIL (\(kT = 0.644\) keV) and LL10 (\(kT = 0.738\) keV).

We then estimated the surface brightness of OV\(\text{II}\) K\(_\alpha\) and OV\(\text{III}\) K\(_\alpha\) emission. We set the Oxygen abundances of the two APEC models to 0 and added two Gaussian functions that represent OV\(\text{II}\) K\(_\alpha\) and OV\(\text{III}\) K\(_\alpha\) emission. We set the intrinsic width of the Gaussian functions to a value small compared to the detector energy resolution. We did not include absorption in the Gaussian components. We set the centroid energies and the normalization parameters of the Gaussians and the normalization parameters of the CXB and APEC components free. We set the intensities of the TAE component to 0 for GB and LH-1, because we had obtained only upper limits for this component. The surface brightness of a line is calculated from the best-fit value of the Gaussian normalization.

The OV\(\text{II}\) K\(_\alpha\) emission is at 666 eV which will therefore blend with the OV\(\text{III}\) K\(_\alpha\) emission at 654 eV. We estimated the OV\(\text{II}\) K\(_\alpha\) intensity from the best-fit value of Gaussian normalization of OV\(\text{II}\) K\(_\alpha\) and subtracted it.
from the Gaussian normalization of O\textsc{viii} $K_\alpha$. The ratio, $u_c$ of O\textsc{vii} $K_\beta$ to O\textsc{vii} $K_\alpha$ intensities is a slow function of the plasma temperature for thermal emission. As we will show later, the temperature of the TAE component determined from O emission is in the range of $kT = 0.19$ to 0.23 keV. Then $u_c = 0.056$. If the emission is due to SWCX, $u = 0.083$ (Kharchenko et al. 2003). We estimated the O\textsc{vii} $K_\beta$ intensity assuming that 2 LU of O\textsc{vii}K is from SWCX and the rest from thermal emission of $kT = 0.19$ to 0.23 keV (see below). The difference of the estimation from the totally SWCX or totally thermal cases is at most 0.2 LU, which is smaller than the statistical errors of O\textsc{viii} intensity.

In Table 5 we summarize the results of the spectral fits. The centroid energy of O\textsc{vii} had to be fixed to the theoretical value for LH-2, because we obtained only an upper limit for this data set. Except for this case, the centroid energies are consistently determined to be equal to their expected values within the systematic errors of energy scale calibration (5 eV, Koyama et al. 2007, also see the Suzaku Technical Description).

The O\textsc{vii} emission intensities of NEP1 and NEP2 are not consistent with each other within the 90\% statistical errors, while the O\textsc{viii} emission intensities are consistent. The difference between the best fit values of O\textsc{vii} is 1.9 LU. In the previous section, we discussed that time variable geocoronal SWCX of 1.5 - 2 LU level can remain in our spectra. Thus, the difference can be partly due to contamination of the geocoronal SWCX. Temporal variations of Heliospheric SWCX could also contribute to the difference.

### 3.2. Correlation between O\textsc{vii} and O\textsc{viii} intensities

In Figure 3, we plot the derived O\textsc{viii} emission intensity as a function of the O\textsc{vii} intensity, and include the data points for M12on and MP235 from Masui et al. (2009). In the figure we notice two remarkable characteristics. First, there is a floor in the O\textsc{vii} intensity at $\sim 2$ LU. Second, all the data points except for three (HL-B, MP235, and LL10) approximately follow the relation (O\textsc{viii} intensity) = 0.5 $\times$ [ (O\textsc{vii} intensity) - 2 LU]. Masui et al. (2009) proposed that the O\textsc{viii} emission line of the midplane field, MP235, is associated with a $\sim 0.8$ keV component that may arise from faint young dM stars in the Galactic disk. As we discuss later, the low latitude field at $b = 10^\circ$, LL10, is also considered to contain emission of similar origin. Such high temperature emission produces little O\textsc{vii}. We thus consider that the floor of O\textsc{vii} emission and the strong
Fig. 3. Relation between O\textsubscript{vii} and O\textsubscript{viii} surface brightnesses for the 14 sky fields observed with Suzaku. The horizontal and vertical bars of data points show the 1 σ errors of the estimation. The contribution of O\textsubscript{vii} K\beta emission in the Gaussian function for O\textsubscript{viii} K\alpha is subtracted (see Table 5 and text). The diagonal lines show the relation between O\textsubscript{vii} and O\textsubscript{viii}, assuming an offset O\textsubscript{vii} emission of 2.1 LU and emission from a hot plasma of the temperature and the absorption column density shown in the figure. The Galactic absorption column density of the observation fields are indicated by the maker size of the data points. The short names of five data points on the intensity floor of O\textsubscript{vii} emission are also shown.

The correlation between additional O\textsubscript{vii} and O\textsubscript{viii} intensities suggest that the O\textsubscript{vii} emission consists of two emission components of different origins; an emission component which emits O\textsubscript{vii} of \sim 2 LU and no or weak O\textsubscript{viii} emission (the floor component), and the other component which emits O\textsubscript{vii} of \sim 0 to \sim 7 LU and the O\textsubscript{viii} intensity is about a half of O\textsubscript{vii} (the linear component).

Taking into account possible systematic error of O\textsubscript{vii} intensity due geocoronal SWCX (\sim 1.5 LU), M12on and LH-2 are also on the floor. The O\textsubscript{vii} emission of the M12on field must arise from the near side of the MBM-12 molecular cloud whose distance is 60 - 300 pc. Assuming the midplane space-averaged neutral density (Ferri`ere 2001), the absorption length of O\textsubscript{vii} emission is estimated to be 300 pc for MP235. The total Galactic absorption column density of LL10 (|b| = 10°) is 2.7 \times 10^{21} \text{cm}^{-2}, through which only 10 % of O\textsubscript{vii} photons can penetrate. These indicate that the floor component is ”local” emission and is associated with the SWCX + LHB component of the spectral model (see also discussion in the first paragraph of section 4.2). The emission temperature of the SWCX + LHB component is \emph{kT} \sim 0.1 \text{ keV} when it is described with thermal emission. This is consistent with the weak O\textsubscript{viii} emission of the floor component.

Then the linear component is likely to arise from more distant part of our Galaxy. It is remarkable that LL21 (|b| = 20°) contains significant component (6.4 - 2 = 4.4 LU), even though the low Galactic latitude. The absorption column density of this direction, 7.2 \times 10^{20} \text{cm}^{-2}, is about quarter of LL10 column density and the transmission of the O\textsubscript{vii} emission is about 54 %. This suggests that a large fraction of the linear component arises from beyond the bulk of Galactic absorption, although the possibility that the difference between LL10 and LL21 is mainly due to spatial fluctuation of the emission measure cannot be ruled out. We thus consider that the linear component is associated with the TAE component. This component emits O\textsubscript{vii} and O\textsubscript{viii} with an intensity ratio of about 2 to 1 and shows field-to-field variations of \sim 0 to \sim 7 LU in O\textsubscript{vii} intensity. The lines in Figure 3 show O\textsubscript{vii} - O\textsubscript{viii} intensity relations for different temperatures and absorption column densities. We have assumed 2.1 LU as the O\textsubscript{vii} floor intensity, using the value for the midplane field (MP235). The lines suggest that the average temperatures along each line of sight of the plasmas emitting the O\textsubscript{viii} emission and the O\textsubscript{vii} emission above the floor are in a relatively narrow range of \emph{kT} \sim 0.19 to 0.23 \text{ keV} if they are arising from collisionally equilibrium plasma
in spite of the large O\textsuperscript{vii} intensity variations (\(\sim 0\) to \(\sim 7\) LU).

In Figure 4, we plotted the O\textsuperscript{vii} and O\textsuperscript{viii} emission intensities as functions of absolute Galactic latitude |\(|\theta|\)| (a), and as a function of absolute ecliptic latitude (b). The two data points marked with an open circle are M12on and MP235. The correlations of O\textsuperscript{vii} and O\textsuperscript{viii} emission intensities to Galactic latitude and ecliptic latitude are not very clear. Near solar minimum, Heliospheric SWCX intensities to Galactic latitude and ecliptic latitude are in spite of the large O\textsuperscript{vii} and O\textsuperscript{viii} emission intensities as functions of absolute Galactic latitude |\(|\theta|\)| (a), and as a function of absolute ecliptic latitude (b). The two data points marked with an open circle are M12on and MP235. The correlations of O\textsuperscript{vii} and O\textsuperscript{viii} emission intensities to Galactic latitude and ecliptic latitude are not very clear. Near solar minimum, Heliospheric SWCX intensities to Galactic latitude and ecliptic latitude are not very clear. Near solar minimum, Heliospheric SWCX intensities to Galactic latitude and ecliptic latitude are not very clear. Near solar minimum, Heliospheric SWCX emission is expected to be enhanced in low ecliptic latitude region of \(\lesssim 20^\circ\) by \(\sim 1.5\) LU (Koutroupa et al. 2006). Such small difference may be masked by the spatial variations of the TAE, systematic errors in geocoronal-SWCX removal, and time variations of Heliospheric SWCX. The relevance of Galactic latitude (for TAE) and ecliptic latitude (for SWCX emission) are discussed in sections 4.2 and 4.1, respectively.

3.3. Spectral models consistently describe O emission

If the O\textsuperscript{vii} emission originates in the two plasma emission components of the model as discussed above, we would expect approximately constant temperature and normalization for the SWCX+LHB component that provides the floor to the O\textsuperscript{vii} rate and a constant temperature (\(kT\) \(\sim 0.2\) keV) for the TAE component with its constant O\textsuperscript{viii}/O\textsuperscript{vii} ratio. However, the results of the spectral fits shown in Table 3 (and Table 4) do not show such tendency. The O\textsuperscript{vii} emission intensities of the SWCX+LHB component estimated using the best-fit parameters in Table 3 vary from 2 to 5.5 LU. The temperature of the TAE component is significantly higher than 0.2 keV and is far from constant.

We consider that this discrepancy is related to the Fe and Ne emission. When we fixed the abundances (Fe to O, and Ne to O ratios) of the hot gas in the spectral fits, the temperature of the TAE component was mostly determined by Fe-L and/or Ne-K emission rather than O emission. Then the temperature and the intensity of the SWCX+LHB component was optimized to fill the remaining emission. We notice relatively large residual near Ne K emission energy, in some of the residual plots in Figure 2. We will now try fixing the temperature and the normalization of the SWCX+LHB component, and allowing the Ne and Fe abundances of the TAE component to vary to see if we can still get good fits and if the temperatures of the second component will be closer to 0.2 keV. This is model 2.

As discussed in the previous subsection, the O\textsuperscript{vii} emission from the three fields, M12on, MP235, and LL10 contains only the SWCX+LHB component. The temperature and normalization (emission measure) derived for that component (see Tables 3 and 4) are, respectively, about 0.11 keV and \(14 \times 10^{14}\) cm\(^{-5}\) str\(^{-1}\) for all three fields, which is consistent with the parameters obtained for model fitting of data from the LMC X-3 vicinity (LX-3) by Yao et al. (2009) (0.103 keV and 18.4 \(\times 10^{14}\) cm\(^{-5}\) str\(^{-1}\)), which were derived from previous XMM-Newton and Suzaku observations of directions with absorption gas. For the model 2 spectral fits, we therefore adopted the best fit value of the midplane observation (Table 3) as representative of SWCX+LHB parameters.

In Table 6 and Figure 5 we show the results of the fits. The \(\chi^2\) values are generally good with the reduced \(\chi^2\) values in the range of 0.95 – 1.28 for the degrees of freedom of 91 – 196, although most of them are larger than those for the fit with the first model in Table 3. For five of the spectra, the abundances were not constrained well. We thus fixed the Fe and Ne abundances to the solar value. For LH-2, the existence of the TAE was not significant. We estimated the upper limit of the intensity fixing the temperature to the average value of the other spectra. Excluding HL-B and LL10, the temperature of the TAE component are in the range of 0.18 to 0.24 keV with an average of 0.22 keV, which is significantly lower than the temperatures obtained by model 1.

In model 2, the strong Fe-L and Ne K lines are explained by over-abundance of those elements. In particular, \(\sim 3\times\) solar abundance was required for Ne for four fields. We consider that the strong Ne and Fe emissions could be also represented by a higher temperature emission component with solar abundances. For model 3, we fixed the temperature and the abundance of the TAE component to the average of model 2 (0.222 keV) and to the solar value, respectively. We introduce a fourth emission component with higher temperature which we denote TAE'. In Table 7, we show the results for the four fields. The resultant \(\chi^2\) values are comparable to those for model 2.

In model 3, the excess Ne and Fe emissions are explained by emission with a temperature in the range of 0.6 to 0.9 keV, and an emission measure of \((1 - 2) \times 10^{14}\) cm\(^{-5}\) str\(^{-1}\).

4. Discussion

4.1. Heliospheric Solar wind charge exchange

Although we have been careful to avoid possible contamination by geocoronal SWCX through the selection procedures discussed in section 2, contributions from SWCX in interplanetary space are at best only partially removed by these methods since the long transit times through the solar system wash out the very large short-term intensity variations seen by monitor satellites located in the ecliptic plane near the Earth. Models of this heliospheric SWCX emission are highly uncertain, but some predict that a large fraction of the Galactic R\textsuperscript{4}5 emission is from this source (Koutroupa et al. 2006; Koutroumpa et al. 2008), making it one of the most severe limitations in determining the true interstellar and halo contributions.

Solar activity affects the solar wind densities and ionization temperature. Near the solar maximum, the slow solar winds which have high ionization temperatures and high densities are ejected from the sun resulting in stronger SWCX induced O\textsuperscript{vii} and O\textsuperscript{viii} emissions (Koutroupa et al. 2006) than in solar minimum. Near the solar minimum, slow solar winds are emitted from the equator region of the sun, and high speed, low-density, low-ionization-temperature winds are emitted from the high latitude region of the sun. Discrepancies between early XMM-Newton or Chandra observations which were also made
Table 6. Results of three-component (CXB, TAE, SWCX+LHB) spectral fit with SWCX+LHB temperature and normalization fixed, and with double broken power law CXB (model 2)

| ID     | $N_{\text{H}}$ (10$^{20}$ cm$^{-2}$) | CXB$^a$ | Ne | Fe | Norm$^d$ | $\chi^2$/dof |
|--------|--------------------------------------|---------|----|----|----------|--------------|
| (GB)   | 1.40                                 | 5.6$^{+0.6}_{-0.7}$ | 0.222$^{+0.111}_{-0.068}$ | 1$^e$ | 1$^e$ | 1.2$^{+1.0}_{-0.9}$ | 95.12/92 |
| (HL-B) | 3.36                                 | 2.5$^{+0.5}_{-0.6}$ | 0.296$^{+0.095}_{-0.049}$ | 1$^e$ | 1$^e$ | 1.6$^{+0.7}_{-0.6}$ | 95.14/88 |
| (LH-2) | 0.56                                 | 3.5$^{+0.4}_{-0.5}$ | 0.222 | 1$^e$ | 1$^e$ | <0.7 | 95.33/100 |
| (HL-1) | 0.56                                 | 5.6$^{+0.5}_{-0.5}$ | 0.237$^{+0.262}_{-0.058}$ | 3.79$^{+6.43}_{-2.02}$ | 2.49$^{+13.60}_{-1.98}$ | 2.0$^{+0.6}_{-0.6}$ | 162.31/127 |
| (OFF-FIL) | 4.19                               | 3.1$^{+0.4}_{-0.4}$ | 0.181$^{+0.008}_{-0.009}$ | 3.53$^{+0.80}_{-1.01}$ | 2.99$^{+2.70}_{-1.21}$ | 15.3$^{+1.1}_{-1.1}$ | 159.33/122 |
| (ON-FIL) | 4.61                               | 5.0$^{+0.5}_{-0.5}$ | 0.239$^{+0.027}_{-0.025}$ | 3.46$^{+1.91}_{-1.19}$ | 1.88$^{+2.51}_{-0.85}$ | 5.2$^{+0.9}_{-0.9}$ | 130.94/117 |
| (HL-A) | 1.02                                 | 4.9$^{+0.5}_{-0.5}$ | 0.243$^{+0.031}_{-0.032}$ | 0.91$^{+1.06}_{-0.78}$ | 0.51$^{+1.16}_{-0.48}$ | 4.3$^{+0.8}_{-0.8}$ | 138.89/115 |
| (M12off) | 8.74                              | 2.0$^{+0.4}_{-0.4}$ | 0.184$^{+0.023}_{-0.030}$ | 1$^e$ | 1$^e$ | 4.9$^{+1.2}_{-1.2}$ | 89.83/91 |
| (LX-3) | 4.67                                 | 8.8$^{+0.5}_{-0.5}$ | 0.213$^{+0.018}_{-0.014}$ | 3.04$^{+1.282}_{-1.168}$ | 3.12$^{+1.978}_{-1.390}$ | 7.7$^{+1.2}_{-1.2}$ | 210.94/196 |
| (NEP1) | 4.40                                 | 3.2$^{+0.5}_{-0.5}$ | 0.191$^{+0.006}_{-0.009}$ | 2.09$^{+0.53}_{-0.47}$ | 1.69$^{+0.70}_{-0.55}$ | 15.3$^{+0.9}_{-0.9}$ | 164.60/120 |
| (NEP2) | 4.30                                 | 3.4$^{+0.4}_{-0.4}$ | 0.206$^{+0.041}_{-0.019}$ | 2.65$^{+1.43}_{-1.34}$ | 1.59$^{+1.743}_{-1.47}$ | 10.8$^{+1.8}_{-1.8}$ | 57.94/55 |
| (LL21) | 7.24                                 | 4.7$^{+0.5}_{-0.5}$ | 0.193$^{+0.019}_{-0.016}$ | 2.00$^{+1.15}_{-0.86}$ | 2.88$^{+3.33}_{-1.33}$ | 11.1$^{+1.7}_{-1.7}$ | 112.77/97 |
| (LL10) | 27.10                                | 2.5$^{+0.7}_{-0.7}$ | 0.752$^{+0.177}_{-0.12}$ | 1$^e$ | 1$^e$ | 1.6$^{+0.7}_{-0.7}$ | 91.44/91 |

$^a$ The absorption column densities for the CXB and TAE components were fixed to the tabulated values.

$^b$ Two broken power-law model was adopted. The photon indexes below 1.2 keV were fixed to 1.52 and 1.96. The normalization of the former index component is fixed to 5.7, and only the normalization of the other component was allowed to vary.

$^c$ The normalization of one of the broken power-law components with the unit of photons s$^{-1}$ cm$^{-2}$ keV$^{-1}$ str$^{-1}$ @1keV.

$^d$ The emission measure integrated over the line of sight, (1/4$\pi$) $\int n_e n_H ds$ in the unit of 10$^{44}$ cm$^{-5}$ str$^{-1}$.

$^e$ The abundance was not constrained well, thus fixed to the solar value.

Table 7. Results of four-component (CXB, TAE, TAE', SWCX+LHB) spectral fit with SWCX+LHB normalization and temperature, and TAE temperature fixed, and with double broken power law CXB (model 3)

| ID     | $N_{\text{H}}$ (10$^{20}$ cm$^{-2}$) | CXB$^a$ | Ne | Fe | Norm$^d$ | $\chi^2$/dof |
|--------|--------------------------------------|---------|----|----|----------|--------------|
| (LH-1) | 0.56                                 | 5.3$^{+0.6}_{-0.6}$ | 0.222 | 1.9$^{+0.6}_{-0.6}$ | 0.746$^{+0.346}_{-0.382}$ | 1.0$^{+0.3}_{-0.3}$ | 160.48/128 |
| (OFF-FIL) | 1.90                              | 2.6$^{+0.5}_{-0.5}$ | 0.222 | 10.3$^{+0.7}_{-0.6}$ | 0.861$^{+0.132}_{-0.115}$ | 0.8$^{+0.4}_{-0.4}$ | 197.26/123 |
| (ON-FIL) | 9.60                               | 51$^{+0.5}_{-0.5}$ | 0.222 | 9.0$^{+1.1}_{-1.0}$ | 0.676$^{+0.094}_{-0.099}$ | 1.9$^{+0.6}_{-0.6}$ | 122.93/118 |
| (LX-3) | 4.67                                 | 8.5$^{+0.6}_{-0.6}$ | 0.222 | 7.4$^{+1.1}_{-1.0}$ | 0.559$^{+0.193}_{-0.193}$ | 1.8$^{+0.7}_{-0.7}$ | 216.50/197 |

$^a$ The absorption column densities for the CXB, TAE, and TAE' components were fixed to the tabulated values.

$^b$ Two broken power-law model was adopted. The photon indexes below 1.2 keV were fixed to 1.52 and 1.96. The normalization of the former index component is fixed to 5.7, and only the normalization of the other component was allowed to vary.

$^c$ The normalization of one of the broken power-law components with the unit of photons s$^{-1}$ cm$^{-2}$ keV$^{-1}$ str$^{-1}$ @1keV. Add 5.7 to obtain the total flux at 1 keV.

$^d$ The emission measure integrated over the line of sight, i.e. (1/4$\pi$) $\int n_e n_H ds$ in the unit of 10$^{44}$ cm$^{-5}$ str$^{-1}$.
Fig. 4. O\text{vii} and O\text{viii} emission intensities as functions of absolute Galactic latitude $|b|$ (a), and as functions of absolute ecliptic latitude (b). The two data points marked with an open circle are O\text{vii} intensities of the MBM 12 on cloud direction and the midplane direction $(235, 0)$. Both are taken from Masui et al. (2009).

near the solar maximum in 2000-2002 and Suzaku observations near the solar minimum were noted by Koutroumpa et al. (2007) and Henley & Shelton (2008). For example, Lockman Hole $(l, b) = (149.1, 53.6)$ by XMM-Newton observations taken in October 2002 show much higher O\text{vii} intensities (7 to 18 LU, Koutroumpa et al. (2007)) than those of Suzaku (2.5 and 4.1 from the present LH-1 and LH-2 fields). Henley & Shelton (2008) showed that O\text{vii} line intensities on and off directions of the shadowing filament (On-FIL and Off-FIL fields) were $10.65^{+0.77}_{-0.82}$ and $13.86^{+1.58}_{-1.49}$ LU for the XMM-Newton observations in 2002 March, while they reported that the intensities were $6.51^{+0.37}_{-0.35}$ and $10.53^{+0.66}_{-0.55}$ LU for the Suzaku observations (statistically consistent with the present results, $5.2^{+1.6}_{-0.6}$ and $9.5 \pm 0.7$ LU). If this difference is due to the different SWCX intensity as the authors suggest, it was brighter by about 5 LU during the XMM-Newton observations. The O\text{vii} emission intensity in the MBM12 on-cloud direction determined by Chandra $(1.79 \pm 0.55)$ and Suzaku $2.93 \pm 0.45$ were marginally consistent within the 90 % statistical errors, although the O\text{viii} emission intensity by Chandra $(2.34 \pm 0.36$ LU) was larger than that of Suzaku $(0.30 \pm 0.20$ LU).

The ROSAT sky survey was able to remove SWCX contributions with time variations on scales of a day or less, which should provide efficiencies in removing geocoronal SWCS similar to the procedures used here. The steadier part of the heliospheric contribution is still present, however, and we might expect it to be considerably larger, since the ROSAT survey was conducted at solar maximum and the Suzaku observations near solar minimum. Both Suzaku and ROSAT are in low Earth orbit, and observing directions of the both satellites are almost perpendicular to the Sun-Earth-line.

We calculated the $R_{45}$ band counting rate expected for the best-fit model parameters of model 1 (Table 3) and model 2 (Table 6). We used the ROSAT response function, "pspec\_gain1\_256.rsp", in CALDB at NASA/GSFC\textsuperscript{5}. Two models gave consistent results within the 1$\sigma$ statistical errors.

Using the database at NASA/GSFC\textsuperscript{6}, we extracted ROSAT $R_{45}$ band average counting rate in a circular sky region of 36 arc minute diameter centered at the Suzaku XIS aim point. The size of the sky region is larger than the Suzaku field of view. However, statistical precision of survey will be inadequate on smaller fields. In Figure 6, we plot the observed ROSAT counting rate as a function of expected counting rate from the Suzaku observation. In the figure we include M12on and MP235 fields using the results from Masui et al. (2009). The horizontal error bars in this figure is 1$\sigma$ statistical errors.

\textsuperscript{5} available from http://legacy.gsfc.nasa.gov/rosat/calib\_data/pspc/cpf/matrices/pspc/powmat\_pspc\_cspmat\_cpsmat\_okr\_l1\_256.rsp

\textsuperscript{6} available from http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/xraybg/xraybg.pl
Fig. 5. Results of spectral fits with SWCX+LHB component fixed (model 2) except for MP235 (last panel). Observed spectra (crosses), best-fit model and its components (step functions) convolved with the instrument response function and residuals of the fit (bottom panels) are shown. The vertical error bars of data points correspond to the 1 $\sigma$ statistical errors. The model parameters of the SWCX+LHB component was taken from the midplane observation, MP235 in Table 4.
Fig. 5. Continued.
Table 8. Comparison with ROSAT all sky survey

| ID     | Suzaku band | RASS band |
|--------|-------------|-----------|
|        | 10^{-6} c s^{-1} arcmin^{-2} | 10^{-6} c s^{-1} arcmin^{-2} |
| 1 (GB) | 86.4 ± 2.6  | 186 ± 21^{c} |
| 2 (HL-B)| 65.6 ± 2.2  | 150 ± 21^{c} |
| 3 (LH-2)| 68.4 ± 1.9  | 85 ± 15    |
| 4 (LH-1)| 103.4 ± 2.0 | 103 ± 16   |
| 5 (Off-FIL)| 130.4 ± 2.3 | 227 ± 34^{c} |
| 6 (On-FIL)| 105.3 ± 2.1 | 118 ± 27^{c} |
| 7 (HL-A) | 103.7 ± 2.2 | 112 ± 17   |
| 8 (M12off)| 60.0 ± 1.8  | 99 ± 20    |
| 9 (LX-3) | 140.0 ± 2.4 | 180 ± 16^{c} |
| 10 (NEP1)| 129.6 ± 2.4 | 158 ± 4    |
| 11 (NEP2)| 119.8 ± 4.0 | 158 ± 4    |
| 12 (LL21)| 109.3 ± 2.8 | 123 ± 14   |
| 13 (LL10)| 31.6 ± 1.8  | 44 ± 9     |
| R1 (M12on)| 20.8 ± 0.9  | 37 ± 11    |
| R2 (MP235)| 58.0 ± 2.3  | 109 ± 21   |

The errors in this table are all at 1-σ significance.

a The intensity expected in the ROSAT R45 band from the Suzaku best-fit model function.
b Average intensity for a circular region of 36′ diameter centered at the Suzaku-observation aim point.
c These directions are considered to be contaminated with the long-term enhancement: data points marked with open boxes in Figure 6.

The observed and expected counting rates are well correlated. However the observed ROSAT counting rates are systematically larger than the rates expected from the present Suzaku best-fit model. The sky directions of the five data points marked with an open rectangle (GB, HL-B, Off-FIL, On-FIL, and LX-3) are on streaks of bright areas which follow the RASS scan path. We thus consider that these are possibly contaminated with the long-term enhancement, i.e. the SWCX from the geocorona, or by the solar X-ray scattering during the ROSAT observations (Snowden et al. 1994). If we exclude these data points, the scatter of the data points from a linear relation is significantly reduced. We then fitted the relation of the remaining nine data points with a linear function: (ROSA T observed rate) = p × (rate expected from Suzaku) + q. We obtained p = 1.08 ± 0.12 and q = (16.1^{+12.5}_{-13.6}) × 10^{-6} c s^{-1} amin^{-2}. The slope p is consistent with unity within the 90% statistical errors, while the offset q is positive.

We consider that a large fraction of the positive offset can be explained by the difference in point source sensitivity of the two sets of observations. For the ROSAT map used in the present analysis, point sources with counting rate > 0.020 c s^{-1} in the R45 band were removed (Snowden et al. 1997). This threshold corresponds to 3.8 × 10^{-11} erg cm^{-2} s^{-1} in 0.47 - 1.21 keV assuming a power-law spectrum of a photon index of 1.95 and an absorption column density of 5.6 × 10^{19} cm^{-2} (see below).

On the other hand, from the energy fluxes and their statistical errors of the point sources we removed from the present Suzaku analysis, we estimate the typical detection threshold for point sources to be 1 × 10^{-14} erg cm^{-2} s^{-1} in 0.47 - 1.21 keV. Thus there is a factor of ∼ 40 difference in the detection threshold. We estimated the average surface brightness of point sources in the flux range of (1 − 38) × 10^{-14} erg cm^{-2} s^{-1} in 0.47 - 1.21 keV, assuming the log N − log S relations in 0.5 − 2 keV band obtained by ROSAT (Hasinger et al. 1996). To convert energy flux in 0.5 − 2 keV to the R45 band, we assumed a broken power-law spectrum with photon indices of 1.96 and 1.4 respectively below and above 1.2 keV and various absorption column densities from 5.6 × 10^{18} cm^{-2} (Lockman hole field) to 1 × 10^{21} cm^{-2}. The result we obtained was (14 − 10) × 10^{-6} c s^{-1} amin^{-2} in the R45 band for N_H = (0.056 − 1) × 10^{20} cm^{-2}. Thus the offset q is consistent with zero if we correct for contribution of point sources in the ROSAT data.

Although the ROSAT all sky survey was carried out near the solar maximum in 1990, the present results show that Suzaku and ROSAT R45-band intensities in at least nine directions were consistent with each other. The intensity of the spectral component for SWCX+LHB in
model 2, which contains O\textsuperscript{VII} emission of 2.1 LU produces a ROSAT R\textsc{45} counting rate of $14 \times 10^{-6}$ c s\textsuperscript{-1} am\textsuperscript{2}\textsuperscript{-1}. Since this is comparable to the 90% confidence upper limit of the offset $q = 17 \times 10^{-6}$ c s\textsuperscript{-1} am\textsuperscript{2}\textsuperscript{-1}, it suggests that on average, the maximum increase in heliospheric O\textsuperscript{VII} emission intensity between the ROSAT and Suzaku is at most $\sim 2$ LU, or a factor of two. Since the solar maximum increase should include lines from higher ionizations states such as O\textsuperscript{VIII} and Ne\textsuperscript{X} that are more efficient in producing R\textsc{45} counts, the increase in O\textsuperscript{VII} is probably much less than this.

In section 2.3, we tried to remove as much as possible the time intervals in which the X-ray spectrum was contaminated by the SWCX from the geocorona. Consistency between the ROSAT and Suzaku data also indicates successful removal.

4.2. Intensity variations and temperature of the TAE

Although the solar wind has a broadly simple structure, with the slow wind confined to low ecliptic latitudes during solar minimum, the spatially non-uniform distribution of neutral H and He around the Sun leads to a complex pattern of SWCX emissivity. The distribution on the sky of observed SWCX emission is also a function of the observer’s particular viewing geometry, as noted for example by Lallement (2004) and Robertson & Cravens (2003), requiring detailed modeling which is beyond the scope of this paper. The general level of SWCX emission in the R\textsc{45} band, however, is expected to be too small to explain the spatial variations observed in our work, consistent with our interpretation in model 2 that the spatially dependent components of O\textsuperscript{VII} emission are associated primarily with the TAE component and not with SWCX.

Yao et al. (2009) constructed a thick hot disk model extending above the Galactic disk in order to simultaneously explain the absorption and emission lines observed in the energy spectra of LMC X-3, the X-ray binary in the LMC, with Chandra, and in the energy spectra of the X-ray diffuse emission in the two directions about 30’ away from LMC X-3 observed with Suzaku. They assumed density and temperature distributions exponentially decreasing in the direction perpendicular to the Galactic disk. They obtained as the best-fit parameters the scale heights of $h_T\xi = 1.4(0.2, 5.2)$ kpc and $h_n\xi = 2.8(1.0, 6.4)$ kpc for temperature and density respectively, and the midplane gas temperature and H ion density of $T_\text{p} = 3.6(2.9, 4.7) \times 10^6$ K and $n_\text{p} = 1.4(0.3, 3.4) \times 10^{-3}$ cm\textsuperscript{-3}, where $\xi$ is the filling factor of the hot gas. The emission-measure weighted average temperature along a line of sight is $T_\text{p}/(1 + h_n/(2h_T)) \sim 0.16$ keV. This is lower than the best-fit temperatures of the TAE component with model 2 Table 6, although the discrepancy is not very large taking the the errors in $T_\text{p}$ and $h_n/h_T$ into account.

For a plane-parallel configuration, we expect the intensity of the emission to increase from high to low latitude as $\propto \sin^{-1}|b|$, with a rapid decrease at low latitudes, $b \lesssim 10^\circ$, due to Galactic absorption with a much smaller scale height than the emission. In Figure 7, instead of O\textsuperscript{VII} emission intensity, we show the emission measure of the TAE component multiplied by $\sin |b|$ as a function of $|b|$. The TAE normalization factors are taken from model 2 (Table 6). The data point LL10 is not plotted because the higher temperature component of this field is like to have a different origin from other fields.

![Fig. 7. The emission measure of the TAE component multiplied by $\sin |b|$ as a function of $|b|$](image)

The short angular scale spatial variation between the two Lockmann hole fields, LH-1 and LH-2, is puzzling. These are separated by only 0.42°, but the TAE component and O\textsuperscript{VII} emission are significantly stronger for LH-1 (Table 7, 5). The ROSAT map also show a difference in R\textsc{45} intensities of the two fields (Table 8), although the field of view of the two ROSAT fields are overlapped. Since the distance between two lines of sight is only 10 pc at 1 kpc away from the sun, the density contrast of hot plasma must be high between outside and inside the blobs. Figure 7 may also indicate that $EM \sin |b|$ is systematically larger for $|b| \lesssim 50^\circ$, than for $|b| \gtrsim 50^\circ$. However, this could be a chance effect, and we need more data points, in particular for $|b| \sim 50^\circ$.

We estimate the parameters of hot gas by assuming an isotropic temperature of $kT = 0.222$ keV for simplicity. The total luminosity of the emission is estimated from the average value of $EM \sin |b|$, assuming a plane parallel density distribution as

$$L = 8\pi^2 \Lambda(T)EM \sin |b|R^2,$$

where $\Lambda(T)$ and $R$ are, respectively, the emissivity per emission measure at a temperature $T$, and the outer cylindrical radius of the emission region. Using the values of $\Lambda(T)$ for bolometric flux (Sutherland & Dopita 1993) and 0.3-2 keV band (APEC), we obtain

$$L_{\text{bol}} = 3.8 \times 10^{39} \text{ erg s}^{-1} \times \left( \frac{EM \sin |b|}{3.6 \times 10^{14} \text{ cm}^{-3} \text{ str}^{-1}} \right) \left( \frac{R}{15 \text{ kpc}} \right)^2,$$

$$L_{0.3-2\text{keV}} = 1.1 \times 10^{39} \text{ erg s}^{-1}.$$
by a higher temperature components of that these Fe-L and Ne "excess" emission can be explained of the spectra. However, in model 3 (Table 7), we showed by a factor of five shorter than the radiative cooling time virial temperature remains, since the escape time scale is potential and that the gas at the temperature near the possible that higher temperature gas has escaped from the at least on this time scale. Another interpretation is also of the hot gas is 3Gy, and the hot gas needs be supplied with the simulations. However, the radiative cooling time luminosity of our Galaxy estimated above is consistent with Table 7 et al. (2005)). A possible explanation for this coincidence is that the hot gas was formed by cosmological accretion (Tif et al. 2002; Rasmussen et al. 2009). The total luminosity of our Galaxy estimated above is consistent with the simulations. However, the radiative cooling time of the hot gas is 3Gy, and the hot gas needs be supplied at least on this time scale. Another interpretation is also possible that higher temperature gas has escaped from the potential and that the gas at the temperature near the virial temperature remains, since the escape time scale is by a factor of five shorter than the radiative cooling time scale.

From the spectral fits with model 2, we obtained 2 to 3 solar for [Ne/O] and [Fe/O] abundance ratios for four of the spectra. However, in model 3 (Table 7), we showed that these Fe-L and Ne "excess" emission can be explained by a higher temperature components of \( kT = 0.5 - 0.9 \) keV. The HL-B field shows a high O emission temperature (0.30 keV, see Figure 3 and Table 6). Since all these fields are in high ecliptic latitudes, where only low-ionization-temperature winds are emitted from the sun during solar minimum, the Heliospheric SWCX is not likely origin of the excess Ne and Fe emission. These lines of sight may contain blobs of high (> 0.22 keV) temperature hot gas which may be on the way to escape from our Galaxy.

### 4.3. The spectrum of the \( b = 10^\circ \) sample

We obtained significantly higher temperature \( (0.75 \text{ keV}) \) for the TAE component for Low Latitude 97+10 (LL10) than that of other samples (average = 0.2 keV). This direction has a high Galactic absorption of \( 2.78 \times 10^{21} \text{ cm}^{-2} \), and the transmissions for OVII and OVIII are respectively only about 10 and 20 \%. Thus the emission from the thick disk of temperature \( \sim 0.2 \text{ keV} \) will be significantly absorbed and hard to detect, if it exists in this direction. Masui et al. (2009) detected an emission component of the similar temperature in the energy spectrum of the midplane direction, MP235. They suggested that the component is a sum of emission from unresolved faint dM stars existing between the bulk of Galactic absorption and the Earth, and constructed model spectra assuming an average dM star spectrum with two-temperature thermal emission, the stellar X-ray luminosity distribution functions, and the spatial densities of dM stars in the literature. The model spectrum could consistently explain the observed spectrum not only in spectral shape but also in absolute intensity within 30 \%. We fitted the LL10 spectrum using their dM star model spectrum constructed for \( (\ell, b) = (90^\circ, 10^\circ) \), instead of the TAE component in model 1. As shown in Figure 8, this model reproduces the observed spectrum well \((\chi^2 = 89.2 \text{ for 90 degrees of freedom})\). However, it was necessary to increase the intensity of the emission by a factor of about 5 from the model. This suggests that the emission from dM stars does not decrease so rapidly with increasing \( b \) as the model predicts, or that the there are large spatial fluctuations at \( b \sim 10^\circ \). We need more observations at low Galactic latitude in order to solve this problem.

\[
\chi^2 = \left( \frac{E^\text{obs} - E^\text{mod}}{\sigma} \right)^2
\]

\[
\left( \frac{E_{\text{midplane}}}{b} \right) \left( \frac{E_{\text{Earth}}}{b} \right) = \left( \frac{R}{15 \text{ kpc}} \right)^2 \left( \frac{h\xi}{1.4 \text{kpc}} \right)^{1/2}
\]

As the scale height, \( h \), of hot gas we assumed the temperature scale height from Yao et al. (2009), since it is smaller than the density scale height.

\[
n_0 = 1.3 \times 10^{-3} \text{ cm}^{-3} \times \left( \frac{E \sin |b|}{3.6 \times 10^{14} \text{ cm}^{-5} \text{ str}^{-1}} \right)^{1/2} \left( \frac{h\xi}{1.4 \text{kpc}} \right)^{-1/2},
\]

and

\[
M_{\text{tot}} = 6.5 \times 10^7 M_\odot \times \left( \frac{E \sin |b|}{3.6 \times 10^{14} \text{ cm}^{-5} \text{ str}^{-1}} \right)^{1/2} \left( \frac{h\xi}{1.4 \text{kpc}} \right)^{1/2} \times \left( \frac{R}{15 \text{ kpc}} \right)^2.
\]

**Fig. 8.** Fit result of the Low Latitude 97+10 (data ID 13) spectrum using the faint dM star model by Masui et al. (2009) instead of the TAE component.
5. Summary

We presented spectra of soft diffuse X-ray emission in twelve fields observed with Suzaku together with the spectra of two other fields analyzed by Masui et al. (2009). In the data reduction, we carefully removed the contributions of the solar-wind charge-exchange (SWCX) induced X-ray emission from the geocorona. However, ~1.5 LU uncertainty remains in O\textsuperscript{vii} components of the solar abundance, one of which are sub-component for the CXB, and two thin thermal emission spectra with a model consisting of a broken power-law between the two NEP observations (1.9 LU) can be partly due to yet incomplete removal of geocoronal SWCX.

To determine O emission intensities, we first fitted the spectra with a model consisting of a broken power-law component for the CXB, and two thin thermal emission components of the solar abundance, one of which are subject to Galactic absorption (model 1). The O\textsuperscript{vii} and O\textsuperscript{viii} emission intensities were determined using the model by setting O abundances of two thermal emission components to zero and adding two Gaussian functions to represent O\textsuperscript{vii} and O\textsuperscript{viii}. The O\textsuperscript{vii} and O\textsuperscript{viii} intensities are strongly correlated and suggest the existence of an intensity floor for O\textsuperscript{vii} emission at ~2 photons s\(^{-1}\) cm\(^{-2}\) str\(^{-1}\) (LU). The O\textsuperscript{viii} emission intensity of nine high-latitude fields show a tight correlation with the excess of the O\textsuperscript{vii} intensity above the floor. The relation is approximated as (O\textsuperscript{viii} intensity) = 0.5 \times [(O\textsuperscript{vii} intensity) – 2 LU]. These suggest that the O\textsuperscript{vii} emission arises from two origins: approximately uniform emission of about 2 LU, and spatially variable (0.7 LU) emission from hot plasma of a temperature of ~2 keV. The former is likely to arise from Heliospheric Solar Wind Charge Exchange plus the local hot bubble (SWCX+LHB), and the latter from hot gas in more distant parts of the Galaxy, i.e. the transabsorption emission (TAE). It is remarkable that for most of the fields, TAE average emission temperatures are confined in a narrow range (~±0.2 keV) around 0.2 keV. This temperature may be related to the virial temperature of the Galaxy, which locally corresponds to the rotation velocity of ~200 km s\(^{-1}\).

The O emission intensities of the two thermal components of model 1 do not reproduce the above characteristics of O emission. This is because the abundance is fixed to the solar, while strong Ne and Fe-L emissions exist in some of the spectra. The observed spectra can be fitted with a model in which the intensity and temperature of the non-absorbed SWCX+LHB component are fixed to nominal values if we set the Ne and Fe abundances of absorbed TAE component free (model 2), or if we include an additional higher temperature component (model 3). We found that four spectra required Ne to O abundances as large as 3 solar with model 2. Alternatively, these spectra can be fitted by model 3 with a higher temperature (0.5 - 0.9 keV) emission component with solar abundances. The temperatures of the TAE component obtained with these two models were consistent with the values expected from the O\textsuperscript{vii} to O\textsuperscript{viii} ratio.

The surface brightnesses estimated from the present best-fit model function were statistically consistent with the ROSAT All Sky Survey (RASS) map, even though the present observations were performed during solar minimum, while the RASS was in solar maximum. The upper limit for the difference was estimated to be 17 \times 10^{-6} \text{ cm}^{-2} \text{s}^{-1} R_{15} \text{band counting rate after corrected for the difference in point source removal threshold between the present Suzaku observations and the RASS.}

The origin of the TAE component was discussed in the context of the thick hot disk constructed by Yao et al. (2009). The emission measure determined by model 2 shows a large deviation from the \(|b|\) dependence expected from a plane parallel configuration, which we consider to suggest short spatial scale structure of the hot gas. The total luminosity, midplane density, and the total mass of the hot gas were estimated assuming simple cylindrical geometry and a uniform temperature. The canonical temperature of the TAE component, \(kT \sim 0.2\) keV, may be related to the virial temperature of our Galaxy.

The lowest latitude sample of the present analysis, \(b = 10^\circ\), contains emission with \(kT = 0.75\) keV instead of 0.2 keV. The spectral shape of this component can be represented by the faint dM star model by Masui et al. (2009). However the intensity must be increased by a factor of about five from the model.

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