Differences of the Galactic Diffuse X-ray Emissions from the Galactic Center, Ridge and Bulge Regions

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Abstract

The Galactic diffuse X-ray emission (GDXE) with highly ionized Fe Kα lines extends from the Galactic center (GC) to the ridge and the bulge. We analyzed the XIS data of the GC regions over $-3^\circ < l < 2^\circ$, $|b| < 1^\circ$ and the region at $(l, b) = (0^\circ, -2^\circ)$, and studied He- and H-like Fe Kα lines. The intensity profiles of He-like Fe Kα line along the Galactic plane are clearly separated into two components. The intensity ratio of H-like Fe Kα to He-like Fe Kα significantly decreases with the distance from Sgr A* along the plane. The intensity profile perpendicular to the plane near the GC has two scale heights. The intensity ratio does not show significant difference over $-2^\circ < b < 0^\circ.7$.

Key words: Galaxy:center — Galaxy:disk — X-rays:ISM — X-rays:spectra

1. Introduction

The Galactic diffuse X-ray emission (GDXE) extends from the Galactic center (GC) to the ridge and the bulge of the Milky Way. The spectra exhibit He- and H-like Fe Kα lines, which are characteristic for thin thermal plasma with a temperature of 5–10 keV. The origin of the GDXE remains an open question.

Koyama et al. (2007) revealed that the spectrum of the GC ($-0^\circ.4 < l < 0^\circ.2$, $-0^\circ.1 < b < 0^\circ$) prefers collisional equilibrium hot plasma to charge exchange as its origin with the data of the Suzaku XIS. They also showed that the intensity profile of He-like Fe Kα of the GC along the Galactic longitude is different from the profile of the point sources obtained with Chandra. It suggests that the major component of the GC emission is not integration of point sources but truly diffuse plasma. On the other hand, Revnivtsev et al. (2007, 2009) resolved more than 35 and 80 % of the GCDX at $(l, b) = (0^\circ.1, 0^\circ)$ and $(0^\circ.1, -1^\circ.4)$ into point sources using the data of Chandra. In addition, Yamauchi et al. (2009) shows that the intensity ratios of H-like Fe Kα to He-like Fe Kα are different between the regions around ($|l| < 1^\circ$, $|b| < 0^\circ.1$) and ($8^\circ < |l| < 28^\circ$, $|b| < 0^\circ.7$).

These results point to a possibility that the origins of the GDXE are different from region to region. Thus systematic study of the spatial profiles and the spectra of the GDXE on various regions are key to solve the origins. The features of He- and H-like Fe Kα lines are especially important. High energy resolution of X-ray CCDs is required to resolve these lines. We report the result of systematic observations of the GDXE using the Suzaku XIS.

2. Observation

We analyzed the Suzaku XIS data of the GC regions over $-3^\circ < l < 2^\circ$, $|b| < 1^\circ$ and the region at $(l, b) = (0^\circ, -2^\circ)$. These regions were observed between Sep. 2005 and Mar. 2008. The total exposure time is about 3.3 M s. This is one of the widest and deepest observations of the GC using X-ray CCD cameras. The X-ray image of the analyzed data except for the $b = -2^\circ$ region is shown in figure 1.

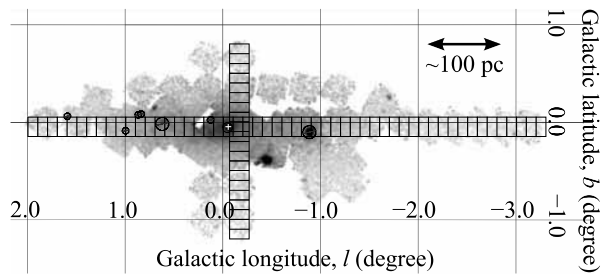

Fig. 1. X-ray image of analyzed XIS data except for the $b = -2^\circ$ region. This image is in the 6.55–6.8 keV band which corresponds to He- and H-like Fe Kα. About 100 pc corresponds $0^\circ.7$ in this image assuming the distance to the GC is 8 kpc. The white cross mark shows the position of Sgr A*. Spectra were extracted from the rectangles along the longitude and latitude. The circular regions around known bright sources were excluded from the spectra.

3. Highly Ionized Fe Kα along the Galactic Longitude

To study the intensity profile of highly ionized Fe Kα along the plane, we extracted spectra from the regions shown with the rectangles along the Galactic longitude in figure 1. The circular regions around known bright sources, such as Sgr A East, were excluded. We fitted the spectra in the 5–10 keV band with the phenomenological model of an absorbed power-low plus four gaussians. The line centers of the gaussians were fixed to 6.40 (neural Fe Kα), 6.68 (He-like Fe Kα), 6.97 (H-like Fe Kα) and 7.06 (neural Fe Kβ) keV. The intensities of these lines were free except for Fe I Kβ whose intensity was fixed to 0.125 times that of Fe I Kα (Kaastra & Mewe 1993).

With these model fittings, the line intensities of the each region were obtained. The obtained intensity profile of He-like Fe Kα along the longitude is shown in figure 2. Here the stellar absorption is not corrected. The results of Yamauchi et al. (2009) are also added there. The latitudes of the data of Yamauchi et al. were $-0^\circ.05 < b < 0^\circ.7$ and different from those of our spectra ($b = -0^\circ.046$). So the data of Yamauchi et al. were corrected assuming the scale height of the intensity profile along the latitude is $0^\circ.5$ (Kaneda et al. 1997).

We fitted this profile with phenomenological models to obtain typical scale heights. A one-component model was tried; $A \times \exp(-l_*/h)$. The distance along the longitude from Sgr A*, which is located at $(l, b) = (-0^\circ.056, -0^\circ.046)$ (Reid & Brunthaler 2004), is l_*. The line intensity at $l_* = 0^\circ$ is A. The one-component model cannot explain the profile of $l_* > 0.6^\circ$. Thus a two-component model was tried; $A_1 \times \exp(-l_*/h_1) + A_2 \times \exp(-l_*/h_2)$. The fitting is significantly improved with this model. The best fit parameters of the two-component model are the following; A_1 and A_2 are $(2.7 \pm 0.2) \times 10^{-6}$ and $(1.6 \pm 0.4) \times 10^{-7}$ photons s^{-1} cm^{-2} arcmin^{-2}, and h_1 and h_2 are $0^\circ.42 \pm 0^\circ.04$ and $33^\circ \pm 6^\circ$.

We also derived the intensity ratio of H-like Fe Kα to He-like Fe Kα from these spectra. The result is shown in figure 3 where the data points are binned to increase statical significance. The ratio decreases significantly from ~ 0.4 to ~ 0.2 along the distance from Sgr A* along the longitude. The ratio reflects the temperature of the hot plasma and this result corresponds the plasm temperature changes from $kT \sim 7$ keV to ~ 5.5 keV. Yamauchi et al. (2009) reported the ratio on the regions of $8^\circ < |l| < 28^\circ$ is ~ 0.22. It is quite similar to the ratio at $l_* \sim 2^\circ.5$, where the larger scale height component dominates.

4. Highly Ionized Fe Kα along the Galactic Latitude

To study the intensity profile perpendicular to the plane near the GC, we extracted spectra from the rectangles along the Galactic latitude shown in figure 1. We also

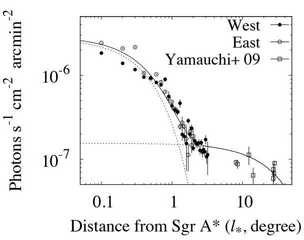

Fig. 2. Intensity profile of He-like Fe Kα along the longitude. The solid and two dotted lines show the best-fit two-component model, h_1 and h_2 components respectively.

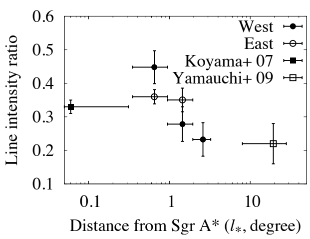

Fig. 3. Line intensity ratio of H-like Fe Kα to He-like Fe Kα along the longitude. The averaged ratios on $-0^\circ.4 < l < 0^\circ.2$ and $8^\circ < |l| < 28^\circ$ are also shown (Koyama et al. 2007, Yamauchi et al. 2009).

extracted a spectrum from the data of $b = -2^\circ$.

We analyzed these spectra in the same way as section 3. The intensity profile of He-like Fe Kα line along the latitude is shown in figure 4. The profile also requires a two-component model like the case of the longitude; $A_1 \times \exp(-b_*/h_1) + A_2 \times \exp(-b_*/h_2)$. The distance from Sgr A* along the latitude is b_*. The definitions of the other parameters are same as before. The best fit parameters are the following; A_1 and A_2 are $(2.1 \pm 0.3) \times 10^{-6}$ and $(3.3 \pm 0.3) \times 10^{-7}$ photons s^{-1} cm^{-2} arcmin^{-2}, and h_1 and h_2 are $0^\circ.16 \pm 0^\circ.04$ and $1^\circ.1 \pm 0^\circ.3$.

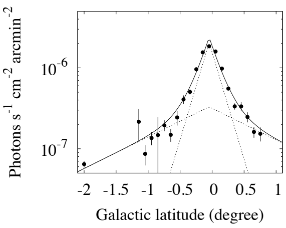

Fig. 4. Intensity profile of He-like Fe Kα along the latitude. The solid and two dotted lines show the best-fit two-component model, h_1 and h_2 components respectively.

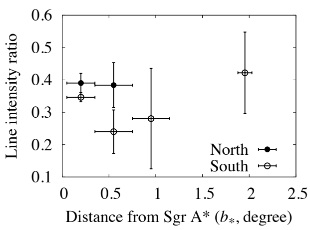

Fig. 5. Line intensity ratio of H-like Fe Kα to He-like Fe Kα along the latitude.

The intensity ratio of He-like Fe Kα to H-like Fe Kα along the latitude is shown in figure 5. The shift of the ratio is not significant over $-2^\circ < b < 0^\circ.7$.

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