Suzaku Observation of Time Variability of X-ray Emission from Molecular Clouds in the Galactic Center

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Abstract

Recently, X-ray emitting molecular clouds in the Galactic center have been discovered. The most possible scenario is that past big flares of the super-massive black hole Sagittarius (Sgr) A* illuminates those molecular clouds. High luminosity $\sim 10^{39}$ erg s$^{-1}$ is derived from the X-ray flux of the molecular clouds while Sgr A* has an averaged luminosity of $2 \times 10^{33}$ erg s$^{-1}$. Black hole activity suddenly decreased by six orders of magnitude in the several decades. We have discovered time variation in the X-ray flux of the molecular clouds. Since the molecular clouds cannot change their shape or density, the variability must be caused by the illuminating source. We performed observations of the prominent molecular clouds in the Sgr A, B, and C regions from 2005 to 2013 with Suzaku. We found that several clouds show time variations and some of them have constant X-ray flux. We discuss the past Sgr A* activity from our results.

Key words: Galaxy: center — ISM: X-ray — X-ray reflection nebulae

1. Introduction

There are several giant molecular clouds (GMC; $M \sim 10^6 M_\odot$) in the 100 pc central region in our Galaxy (e.g. Tsuboi et al. 1999). Recent X-ray observations discovered that some of GMCs exhibit strong X-ray emission (e.g. Sunyaev et al. 1993; Koyama et al. 1996). The sources have similar X-ray spectra with prominent Fe I K line and deep Fe K absorption edge. These features can be a sign of X-ray reflection on the GMCs: photo-absorption and fluorescence. These features prefer to X-ray reflection scenario that a bright source illuminated GMCs in the vicinity (X-ray reflection nebula=XRN, e.g. Koyama et al. 1996; Murakami et al. 2000). The most possible candidate is Sagittarius (Sgr) A*, a supermassive black hole on the Galactic center.

From the GMC mass and X-ray flux, Sgr A* would have $L_X \sim 10^{39}$ erg s$^{-1}$ several hundred years ago (Nobukawa et al. 2008; Ryu et al. 2013). On the other hand, the current luminosity is $\sim 10^{33}$–$10^{36}$ erg s$^{-1}$ (Baganoff et al. 2003; Neilsen et al. 2013). Thus, there must be large variability in the Sgr A* activity. Recently, Suzaku and other satellites discovered time variability of the X-ray emission from XRN in several years (e.g. Inui et al. 2009; Ponti et al. 2010; Nobukawa et al. 2011). Since the GMCs cannot change their density and shape, the variability is the nature of Sgr A* in the past.

In order to take more information, we performed Suzaku observations of XRN in Sgr A, B, and C regions from 2005 to 2013.

2. Results

Figure 1 shows the X-ray band image in 6.3–6.5 keV of Sgr A, B, and C during 2005–2013. NXB subtraction and correction of XRT vignetting effect were taken into account for each image.

2.1. Sgr A

Sgr A is the brightest region in Fe I Kα. The Suzaku aim point is shifted to the eastern direction from the position of Sgr A*; $(l, b) = (-0^{\circ}.05, -0^{\circ}.05)$. There are several XRN (region A–E in figure 1). We found that these sources may have no constant flux. To measure the Fe I Kα line flux, we extracted the spectra and fitted them with Gaussians and power law. The top-right panel in figure 1 shows light curves of the line flux for each XRN. We found that region A has constant flux but regions B, C, D show time variation. Flux in region C significantly rises up by $\sim 50\%$ in 2013 in comparison with 2005–2007. Ponti et al. (2010) reported similar
time variation with the XMM-Newton data during 2000–
2009.

We detected the time variability of Fe I \( \lambda \) from the
Arches cluster (region E) for the first time. The flux
dropped down about by half between 2007 to 2013.

2.2. Sgr B

Sgr B2 (region F) is the most important XRN. Time
variability was already reported (Koyama et al. 2008).
Inui et al. (2009) suggested that Sgr B2 became the most
luminous in 2000 and fell at the \(~ 60\%\) flux in 2005.
Compared with our result, the recent flux in 2013 was
roughly \(~ 5\%\) of the peak. Takagi et al. (2002) reported
young stellar objects (YSO) in the Sgr B2 cloud exhibit
strong Fe lines. The residual emission in 2013 might be
the contribution of the YSOs. On the other hand, while
region G and I also darkened from 2005 to 2013, region
I becomes bright.

2.3. Sgr C

We see two XRNe, J and K, in Sgr C. X-ray flux in
regions K and J decreases by 50\% and \(~ 20\%\), respec-
tively. We see that the bright spot in region J has
moved to the right side, which corresponds to the op-
posite direction from Sgr A*. We estimated the distance
of \(~ 50'' = 7\) light years, which is consistent with the

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References