Suzaku observation of the unidentified gamma-ray source TeV J2032+4130

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Abstract

We observed the first unidentified TeV γ-ray source TeV J2032+4130 with Suzaku. With the high sensitivity for detection of diffuse X-ray emission, we found a structure in the TeV emitting region, which is coincident with a γ-ray pulsar. By subtracting the contribution of point sources estimated by Chandra observation, we obtained X-ray spectrum of diffuse component. The spectrum can be reproduced by a power-law model with a photon index of $\sim$2, and an X-ray flux of 2×10^{-13} erg s^{-1} cm^{-2}. The ratio of the γ-ray flux to the X-ray flux is $\sim$10. If the origin of TeV γ-ray is inverse Compton scattering of microwave background by TeV electrons, which are responsible to synchrotron emission, this ratio corresponds to the magnetic field of $\sim$1 μG.

Key words: acceleration of particles — X-rays: individual (TeV J2032+4130) — X-rays: ISM — pulsars: individual (PSR J2032+4127)

1. Introduction

Stereoscopic technique of atmospheric Cerenkov telescopes improved the angular resolution for detecting TeV γ-rays, and increased the number of TeV γ-ray sources. Some of new TeV objects have no counterparts at other wavelengths. They are called unidentified TeV γ-ray objects. Unidentified TeV γ-ray objects have key information to study acceleration mechanism of cosmic rays. Multi-wavelength observations of these objects are vitally important to reveal the emission mechanism.

TeV J2032+4130 is the first unidentified TeV γ-ray source discovered by HEGRA (Aharonian et al. 2002). The position is coincident with OB association, Cyg OB2. Recently, the large area telescope on the Fermi Gamma-ray Telescope detected γ-rays from this region with the energy from 20 MeV to 300 GeV. In addition, this γ-ray source exhibits pulsation with the frequency of 6.98 Hz (PSR J2032+4127, Abdo et al. 2009). Successive observation of radio band also detect pulsation. The position of the pulsar is revealed to be coincident with MT91 213 (Camilo et al. 2009, Massey & Thompson 1991). These results imply that the origin of TeV γ-ray also relates to this γ-ray pulsar.

2. Observations

2.1. Suzaku

We observed TeV J2032+4130 with Suzaku (Mitsuda et al. 2007) on 2007 December 17–18. After the standard filterings, the net observing time was about 40 ksec.

2.2. Chandra

Chandra observed TeV J2032+4130 twice: earlier short observation (November 2002, obsid=4358) and deep follow-up observation (July 2005, obsid=4501). We only analyzed the latter data set. The exposure time is about 49 ksec. The detailed results about the Chandra observation has already been reported in Butt et al. (2006).

3. Results

3.1. Images

Fig. 1 shows XIS image in 0.5–10.0 keV band. All three CCD data are combined. A white solid circle indicates the TeV diffuse emission region with the center position of (RA, Dec) = ($20^{\rm h}31^{\rm m}57^{\rm s}.0$, $41^\circ29'56''.8$) and the radius of 6'.2 (Aharonian et al. 2005). There are two small structures in the circle (source 1, 2 in Fig. 1).

This X-ray emitting region is located at the north part of Cyg OB2 association and there are many point sources. So we estimate the contribution of the point sources by using the Chandra deep exposure observation.

We extract point sources by the CIAO 'wavdetect' software of a wavelet method.Source 1 and 2 region includes 8 and 2 sources respectively. One of the point sources in source 1 is coincident with the γ-ray pulsar discovered by Fermi (Camilo et al. 2009). The detection of diffuse X-ray emission in this region has been reported by Mukherjee et al. (2007). We also analyze source 1 of suzaku data.

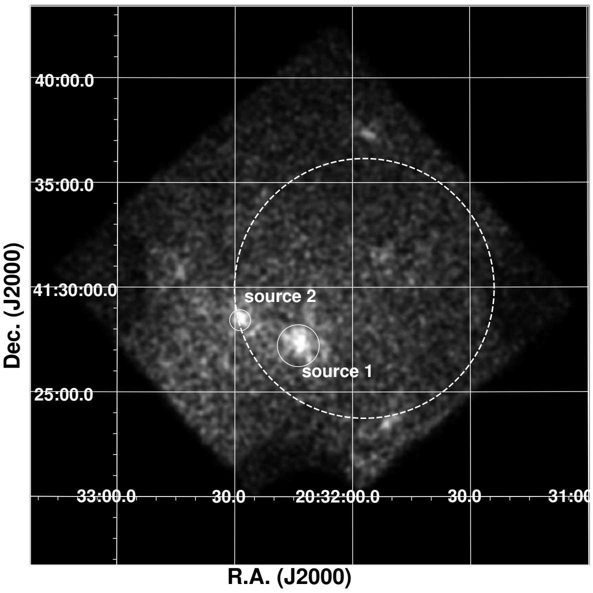

Fig. 1. Suzaku image of TeV J2032+4130 (0.5–10.0 keV). Dashed circle indicates the region of diffuse TeV emission. X-ray structures are shown in solid circles.

3.2. Spectra

At first, we made a spectrum of point sources by Chandra observation in order to estimate the contribution of point sources. We collect all the events from the point sources in source 1 and make a combined point-source spectrum. We fit the spectrum by a power-law model with an interstellar absorption. The best-fit parameters are shown in Table 1.

Then we made the spectrum of source 1 by Suzaku data. Extracted spectrum is shown in Fig. 2(a). We include the contribution of the point sources by adding its best-fit model into the model spectrum. The spectrum of point sources is indicated by dotted line in Fig. 2(a).

Thus we obtained best-fit parameters of diffuse X-ray emission (Table 1). The spectrum can be reproduced by absorbed power-law with the photon index of 2.1, and absorption column of 0.6 $\times 10^{22}$ cm^{-2}. The X-ray flux is about 2.0×10^{-13} erg s^{-1} cm^{-2} (2.0–10.0 keV).

Table 1. Best-fit parameters of X-ray spectra

	N_{H}^{*} (cm^{-2})	$\Gamma^{\dagger}$	$F_{\mathrm{X}}^{\ddagger}$ (erg s^{-1} cm^{-2})
point sources	0.4×10^{22}	3.1	0.3×10^{-13}
diffuse	0.6×10^{22}	2.1	2.0×10^{-13}

*: Column density †: Photon index

‡: X-ray flux in the 2–10 keV band

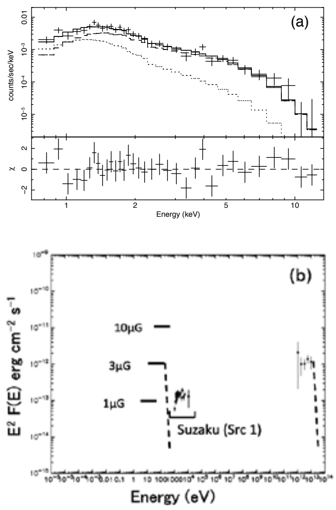

Fig. 2. (a) Suzaku spectrum of source 1. Contribution of point sources is indicated by dotted line. Dashed line shows diffuse component. (b) Multiband spectrum of TeV J2032+4130. Solid lines show synchrotron radiation models with various magnetic field. Dashed line shows an energy cutoff model.

4. Discussion

We obtained X-ray flux of diffuse emission around γ-ray pulsar. Here we compare the X-ray flux to TeV γ-ray flux to investigate the emission mechanism. On the other hand, the GeV γ-ray emission, detected by Fermi, exhibits a large pulse fraction. The main part of GeV γ-ray should be radiated by pulsar. While diffuse emission of TeV and X-ray could be emitted by pulsar wind nebula. In Fig. 2(b), we plot the fluxes of X-rays and TeV γ-rays. If the origin of TeV γ-ray is inverse Compton scattering of cosmic microwave background by TeV electrons, the same high energy electrons also emit X-rays by synchrotron radiation. In this case, the ratio of TeV flux to the X-ray flux depends only on magnetic filed. For source 1, the ratio of flux between TeV and X-ray band $F_{\mathrm{TeV}}/F_{\mathrm{X}} \sim 10$. This value corresponds to the magnetic filed of about 1 μG (solid line in Fig. 2(b) labeled 1 μG). However, this value is much smaller than that expected in this region because of the low Galactic latitude and active star forming region. Strong cutoff of the energy distribution of TeV electrons or hadronic origin of TeV emission should be considered.

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