Observation of Very High Energy Gamma Rays from SS433/W50 with CANGAROO-II Telescope

Seiichi Hayashi and Fumiyoshi Kajino
Department of Physics, Konan University, Kobe, Hyogo 658-8501, Japan
Tsuguya Naito
Faculty of Management Information, Yamanashi Gakuin University, Kofu, Yamanashi 400-8575, Japan
for the CANGAROO-II collaboration

Abstract

SS433 is a unique star located at the center of supernova remnant called W50, and is a close proximity binary star system which consists of a compact star and a normal star. Jets of material are directed outwards from the vicinity of the compact star symmetrically to the east and west. The radiation of non-thermal X-rays considered to have been formed by the jets is detected at both of X-ray lobes by Einstein observatory, and confirmed by ROSAT and ASCA, respectively. Observation of the western X-ray lobe region was performed by the CANGAROO-II telescope in August and September, 2001. We present a preliminary result of our observation in this paper.

1. Introduction

Galactic SNR W50 (G39.7-2.0) is a strong non-thermal radio source. Radio maps of W50 show a $2^\circ \times 1^\circ$ ellipsoidal shape with limb-brightened "ears" elongated in the east-west direction (Geldzahler, Pauls, & Salter 1980; Downes, Salter, & Pauls 1981; Downes, Pauls, & Salter 1986; Elston & Baum 1987). The flux density of W50, which changes with places, is $70 \sim 419$ mJy at 4.75 GHz, and the spectral index is $\alpha = 0.3 \sim 1.02$ at $0.41 \sim 4.75$ GHz (Downes, Pauls, & Salter 1986). The distance to W50 is estimated to be about 5 kpc, and the age to be 10000 year. SS433 at R.A. (J2000) = $19^h 11^m 49^s$, Dec.(J2000) = +04°58'48" is the jet object of 14.2 magnitude located at the center of W50, and is a close proximity binary star system with an orbital period 13.1 days which consists of a compact star and a normal star. Jets of material are directed outwards from the vicinity of the compact star symmetrically to the east and west at the speed about 0.26 c, and precessing in a cone of half-angle 20 degrees, with a precession period of ∼163 days (Fabian & Rees 1979; Milgrom 1979; Abell & Margon 1979).

pp. 1–8

They interact with the SNR shell.

The X-ray lobes of SS433/W50 were discovered by Einstein observatory (Watson et al. 1983), and confirmed by ROSAT and ASCA (Safi-Harb & Ogelman 1997). The X-ray spectrum of each lobe has no apparent emission lines, and is well described by power-law models. They are considered to have been formed by the jets from SS433. At $\sim$1° east of SS433, soft X-ray emission coincident with the radio "ears", which is associated with the terminal shock of the SS433 jets. According to the results of ASCA (Yamauchi et al. 1994), it was found that the spectrum of each X-ray lobe becomes harder as distance from SS433 decreases. Moreover, the western region, closer to SS433, has a harder spectrum than the east region, and the surface brightness of X-ray lobes are almost the same as each other. The spectra of the western lobe divided into three regions are reported by the latest analysis of ASCA (Namiki et al. 2000).

In 1998 and 1999 observing seasons, the HEGRA CT-System searched for TeV gamma-rays from the eastern lobe (Rowel et al. 2001). They concentrated on the jet termination region of the eastern X-ray lobe, a total 19.3 hours observations (after removing bad weather) were accepted for analysis. An analysis of the eastern lobe by the HEGRA CT-System revealed no evidence for TeV emission at photon energies above 1 TeV, with resulting 99% upper limits in the range 8 - 10% of the Crab flux.

2. Observations

Observations of the western X-ray lobe region were performed by the CANGAROO-II 10m telescope (Mori et al. 2001) in August and September, 2001, and in July and September 2002. The tracking position was the jet shock region of the western X-ray lobe at R.A. (J2000) = $19^h10^m17^s$, Dec. (J2000) = +04°57'46", which was the closest region to SS433 of the western X-ray lobe and was the center of the region where the ASCA indicated that there had the hardest spectrum of the western X-ray lobe (Namiki et al. 2000). Also the region was closer to the Galactic Plane, then the density of matter was expected to be higher than that of the eastern lobe. The total observation time in 2001 was 51.4 hours and 49.5 hours for ON and OFF source run, and that in 2002 was 33.8 hours and 31.3 hours, respectively. The maximum elevation angle was about 54 degrees, and the elevation was larger than 40 degrees in almost all observations.

3. Analysis

To reduce night-sky background noise, we selected the data having at least 4 adjacent pixels with the gain more than $\sim$3.3 photoelectrons, by which the stable shower rate could be obtained. The data with shower rate less than 1.5Hz were not used for the present analysis to eliminate the effect of cloudy day and dew condensation on the mirrors. Moreover, in order to make the shower rate stable, the data for which the elevation angle was less than 40 degrees were also not used. After selecting data with good weather conditions by such selections, 66.1% of the total observation time was accepted for the analysis. Observed and selected time are listed in Table 1. To clean up the data, the data which had the arrival time too far (> 30 *nsec*) from the mean arrival time was eliminated. Moreover, 8 PMTs which seemed to be noisy were rejected.

		Observed [hours]	Selected [hours]
Aug and Sep, 2001	ON	51.4	36.3
	OFF	49.5	30.4
	TOTAL	100.9	66.7

Table 1. Observation time. After selection of good weather condition, 66.1% of the total observation time was accepted for 2001 data. 2002 data has not been analyzed yet.

The analysis of the data was based on the imaging atmospheric Cherenkov technique (Hillas 1985; Weekes et al. 1989). We used 4 parameters of *distance*, *length*, *width* and *alpha*. To determine the range of parameter values, we compared the distributions of *distance*, *length* and *width* for the gamma ray data made by the Monte Carlo simulation and OFF source data. Figure 1 shows comparisons between the gamma ray and OFF source data for the respective parameters. The numbers of events of the gamma ray and OFF source data were normalized for ease of comparison. We determined the range of cut values as,

$$\begin{aligned} 0.1 &< distance < 1.1 \\ 0.07 &< length < 0.23 \\ 0.02 &< width < 0.11 \ , \end{aligned}$$

where the maximum acceptance of gamma rays was obtained.

4. Result

Here we show the *alpha* distribution for the tracking position of the telescope in Fig. 2. The distribution of ON source data was normalized by the ratio N_{OFF}/N_{ON} (for $alpha < 30$ degrees). This result is very preliminary and further analysis is required. Moreover, it will be necessary to analyze other regions, since the whole western lobe is contained in the field of view of the CANGAROO-II 10m telescope.

5. Summary

The western X-ray lobe region of SS433/W50 was observed with the CANGAROO-II 10m telescope. We obtained very preliminary results of the analyzed data for the tracking position (R.A. = $19^h10^m17^s$, Dec. = +04°57'46"). We will further analyze the data by adding the data obtained in 2002.

References

[1] Abell, G.O., & Margon, B. 1979, Nature, 279, 701
[2] Brinkmann, W., et al. 1996, A&A, 312, 306
[3] Downes, A.J.B., Pauls, T., & Salter, C.J. 1986, MNRAS, 218, 393
[4] Downes, A.J.B., Salter, C.J., & Pauls, T. 1981, A&A, 103, 277
[5] Elston, R., & Baum, S. 1987, AJ, 94, 1633
[6] Fabian, A.C, & Rees, M.J. 1979, MNRAS, 187, 13
[7] Geldzahler, B.J., Pauls, T., & Salter, C.J. 1980, A&A, 84, 237
[8] Hillas, A. M. 1985, Proc. 19th Internat. Cosmic Ray Conf. (La Jolla), 3, 445
[9] Milgrom, M. 1979, A&A, 76, 3
[10] Mori, M., et al. 2001, Proc. 27th Internat. Cosmic Ray Conf. (Hamburg), 5, 2831
[11] Namiki, M., et al. 2000, Adv. Space Res., 25, 709
[11] Namiki, M., Kawai, N., Kotani, T. 2000, private communication
[12] Rowel, G.P., et al. 2001, Astro-ph/0104288
[13] Safi-Harb, S., & Ogelman, H. 1997, ApJ, 483, 868
[14] Yamauchi, S., et al. 1994, PASJ, 46, L109
[15] Weekes, T.C., et al. 1989, ApJ, 342, 379

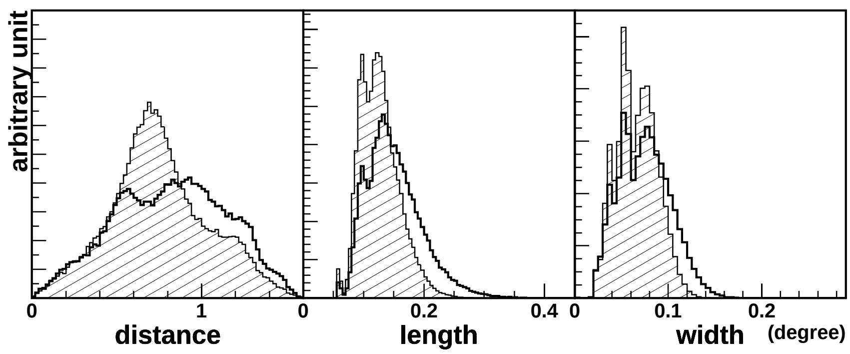

Fig. 1. Distributions of the shape parameters for *distance, length and width.* The hatched and the non-hatched distribution show the Monte Carlo simulation for gamma ray incidents and OFF source data, respectively. The numbers of events are normalized.

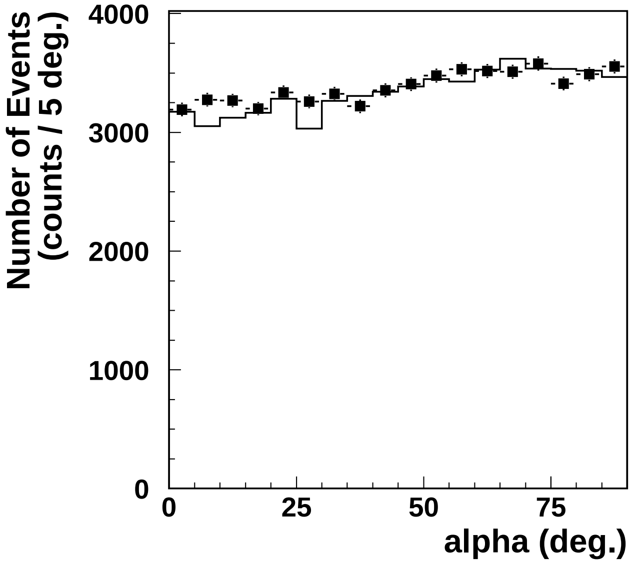

Fig. 2. Alpha distribution for the tracking position. The solid squares show results for the ON source and the solid line show the OFF source, respectively. The distribution of the ON source data was normalized by the ratio N_{OFF}/N_{ON} above 30 degrees. This result is very preliminary.