Search for TeV Gamma Rays from the SNR RXJ1713.7−3946

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Abstract

The shell type SNR RXJ1713.7−3946 is a new SNR discovered by the ROSAT all sky survey. Recently, strong non-thermal X-ray emission from the northwest part of the remnant was detected by the ASCA satellite. This synchrotron X-ray emission strongly suggests the existence of electrons with energies up to hundreds of TeV in the remnant. This SNR is, therefore, a good candidate TeV gamma ray source, due to the Inverse Compton scattering of the Cosmic Microwave Background Radiation by the shock accelerated ultra-relativistic electrons, as seen in SN1006. In this paper, we report a preliminary result of TeV gamma-ray observations of the SNR RXJ1713.7−3946 by the CANGAROO 3.8m telescope at Woomera, South Australia.

1 Introduction:

The recent result of the observation of type Ia SNR SN1006 by ASCA demonstrates that there exist electrons with energies up to ~ 100 TeV which are accelerated within the shock front of the remnant (Koyama et al. 1995). This finding is strong evidence for the SNR origin of cosmic rays. The existence of electrons with energies around 100 TeV is demonstrated more directly by the CANGAROO observation of TeV gamma-rays from the northeast rim of SN1006, which coincides with the region of maximum flux in the 2–10 keV band of the ASCA data (Tanimori et al. 1998). This TeV gamma-ray emission was explained as the 2.7 K cosmic background photons up-scattered by electrons with energies up to ~ 100 TeV by the IC process and allowed, together with the observation of non-thermal radio and X-ray emission, the physical parameters of the remnant, such as the magnetic field strength, to be estimated (Mastichiadis 1996 ; Mastichiadis & De Jager 1996 ; Yoshida & Yanagita 1997 ; Pohl 1996).

Recently, a new shell type SNR, RX J1713.7−3946, was discovered in the ROSAT all-sky survey (Pfeffermann et al. 1996). The remnant has a slightly elliptical shape with a maximum extent of $\sim$ 70′. The total thermal X-ray flux from the whole remnant was estimated as $\sim 4.4 \times 10^{-10}$ erg cm^{-2} s^{-1} in the $0.1 - 2.4$ keV energy band, ranking the remnant among the brightest galactic supernova remnants. The remnant was put at a distance of 1.1kpc, with an age of only ~ 2100 years from the Sedov solution. Subsequent observations of this new remnant by the ASCA Galactic Plane Survey revealed strong non-thermal hard X-ray emission from the northwest (NW) rim of the remnant that is three times higher than that from SN1006 (Koyama et al. 1997). It is suspected that the X-rays from

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RX J1713.7−3946 are dominated by this non-thermal emission from the NW rim. The dominance of non-thermal emission from the shell is reminiscent of SN1006. Koyama et al. proposed from the global similarity of the new remnant to SN1006 – in its shell type morphology, the non-thermal nature of the X-ray emission, and apparent lack of central engine like a pulsar – that RX J1713.7−3946 is the second example, after SN1006, of synchrotron X-ray radiation from a shell SNR.

If this scenario is correct, there is the possibility of observing TeV gamma-ray emission from the new remnant as seen in SN1006. With this motivation, we have observed RX J1713.7−3946 with the CANGAROO imaging TeV gamma-ray telescope in 1998. Here we report a preliminary result of these observations.

2   Instrument and Observation:

The CANGAROO 3.8m imaging TeV gamma-ray telescope is located near Woomera, South Australia ($136°47'$E, $31°06'$S) (Patterson & Kifune 1992 ; Hara et al. 1993). A high resolution camera of 256 photomultiplier tubes (Hamamatsu R2248) is installed in the focal plane. The field of view of each tube is about $0°.12 \times 0°.12$, and the total field view of the camera is about $3°$. The pointing accuracy of the telescope is less than $0°.02$ from a study of the trajectory of bright stars in the field of view (Yoshikoshi 1996). The point-spread function (PSF) of the telescope is estimated to have a standard deviation of $0°.18$ when fitted with a Gaussian function assuming a point source. The sensitivity of our telescope for an integral flux above 2 TeV is estimated as $\sim 2 \times 10^{-12}$ photons cm^{-2} s^{-1} at zenith angle of $20°$ which is the average value for the observations of RX J1713.7−3946 from the CANGAROO telescope site.

RX J1713.7−3946 was observed from May to August in 1998. During on-source observations, the center of the field of view was pointed to the NW rim, which is the brightest region in the hard X-ray band. The total observation time was 66 hours for on-source data and 64 hours for off-source data. After rejecting data affected by cloud, a total of 42 hours of on- and off-source data remained for this analysis.

3   Analyses and Preliminary result:

The imaging analysis of the data is based on the usual parameterization of the elongated shape of the Cerenkov light image using "width," "length," "concentration" (shape), "distance" (location), and the image orientation angle "alpha" (Hillas 1985 ; Weekes et al. 1989 ; Reynolds et al. 1993). The values of these parameters differ from an image by gamma-rays to that by cosmic rays and are utilized to discriminate gamma-ray events from background cosmic ray events. The parameter "alpha" is most efficient in this discrimination. The application of this technique to data recorded with the CANGAROO telescope has, to date, resulted in the detection of TeV gamma-rays from PSR 1706−44 (Kifune et al. 1995), Crab pulsar/nebula (Tanimori et al. 1994, 1998), Vela pulsar (Yoshikoshi et al. 1997) and SN1006 (Tanimori et al. 1998).

Figure 1 shows the resultant alpha distribution when we selected gamma-ray like events with the criteria of $0°.01 \leq$width$\leq 0°.1$, $0°.1 \leq$length$\leq 0°.4$, $0.4 \leq$concentration≤ 0.9 and $0°.5 \leq$distance$\leq 1°.2$ with the NW rim of RX J1713.7−3946 as the center of the field of view. The solid line and the dashed line indicate the on-source and off-source data respectively. Some excess can be seen at alpha $\sim 0°$ for the on-source data. The fact that significance does not fall significantly with the wider alpha acceptance, suggests the emitting region of TeV gamma-rays is extended as in the case of SN1006. Although this preliminary analysis yields a 5.0 σ excess we require a more complete analysis and confirming observations before RX J1713.7−3946 can be declared an established TeV gamma-ray source.

In order to examine if the TeV gamma-rays are emitted from extended regions, the significances of events with alpha $\leq 20°$ were calculated at all grid points in $0.05°$ steps in the field of view. The

resulting contour map of significances is shown in Figure 2, in which the contours of the hard X-ray flux also are overlaid as solid lines (Tomida 1999). The region which shows the emission of TeV gamma-rays with relatively high significance seems to be extended and to coincide with the ridge of the NW rim, which is the bright region in hard X-rays as seen by ASCA.

ASCA reported that the non-thermal X-ray flux from RX J1713.7−3946 is three times higher than that from SN1006 (Koyama et al. 1997). Accordingly it may be interesting to compare the flux of TeV gamma-rays from RX J1713.7−3946 with that from SN1006. If we estimate tentatively the integral flux of TeV gamma-rays from the remnant of RX J1713.7−3946 based on the Monte Carlo simulation method by assuming the emission is from a point source, the value is roughly 3×10^{-12} cm^{-2} s^{-1} (≥ 2 TeV). This value is comparable to that from SN1006. However it is premature to discuss quantitatively the difference or the similarity between the two SNRs due to the preliminary nature of our TeV gamma-ray result and also due to an absence of detailed radio data for RX J1713.7−3946.

4 Summary:

We have observed a marginal excess emission of TeV gamma-rays from the shell type SNR RX J1713.7−3946. The emitting region seems to be extended and to coincide with the NW rim of the remnant bright in hard X-rays as seen by ASCA. The SNR RX J1713.7−3946 is reminiscent of SN1006 both in the synchrotron X-ray emissions from the shell of the remnant and also in the TeV gamma-ray emissions from an extended region coinciding with the region emitting the non-thermal X-rays. Further investigation of the TeV gamma-ray emission from RXJ1713.7−3946 will give us valuable information for a better understanding of particle acceleration processes in SNRs.

References

Hara, T., et al. 1993, Nucl. Inst. Meth. Phys. Res. A 332, 300

Hillas, A. M. 1985, 19th Int. Cosmic Ray Conf. (La Jolla) 3, 445

Kifune, T, et al. 1995, ApJL 438, L91-L94

Koyama, K., et al. 1995, Nature 378, 255

Koyama, K., et al. 1997, PASJ 49, L7

Mastichiadis, A. 1996, A&A 305, L53

Mastichiadis, A. and de Jager.O.C. 1996, A&A 311, L5

Patterson, J. R., and Kifune, T. 1992, Australian New Zealand Phys. 29, 58

Pfeffermann, E., Aschenbach B. 1996, in Roentgenstrahlung from the Universe, International Conference on X-ray Astronomy and Astrophysics, ed H.U. Zimmermann, J.E. Truemper, H. Yorke, MPE Report 263, P267

Pohl, M. 1996, A&A 307, 57

Reynolds, P. T., et al. 1993, ApJ 404, 206

Tanimori, T, et al. 1994, ApJL 429, L61-L64

Tanimori, T, et al. 1998, ApJL 492, L33-L36

Tanimori, T, et al. 1998, ApJL 497, L25-L28 and Plate L2

Tomida, H. 1999, Ph. D. thesis, Kyoto University

Weekes, T.C., et al. 1989, ApJ 342, 379

Yoshida, T. and Yanagita, S. 1997, Proc. 2nd INTEGRAL Workshop 'Transparent Universe' ESASP-382, 85

Yoshikoshi, T. 1996, Ph. D. thesis, Tokyo Institute of Technology

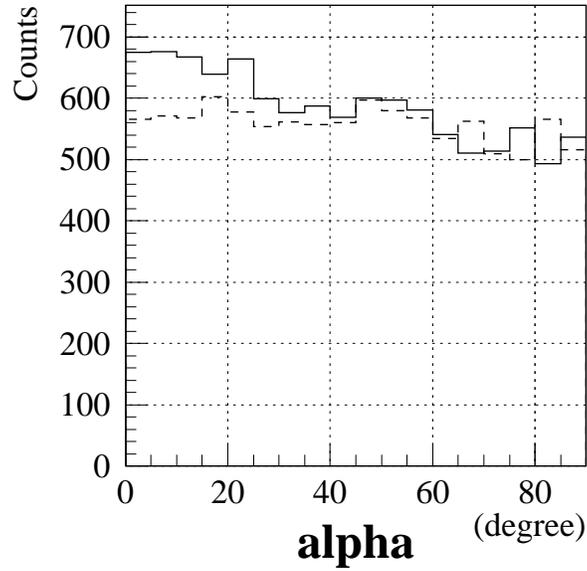Yoshikoshi, T, et al. 1997, ApJL 487, L65-L68

Figure 1: Distributions of the image orientation angle "alpha" with respect to the direction of the NW rim, where the solid line is for on-source data and the dashed line is for off-source data.
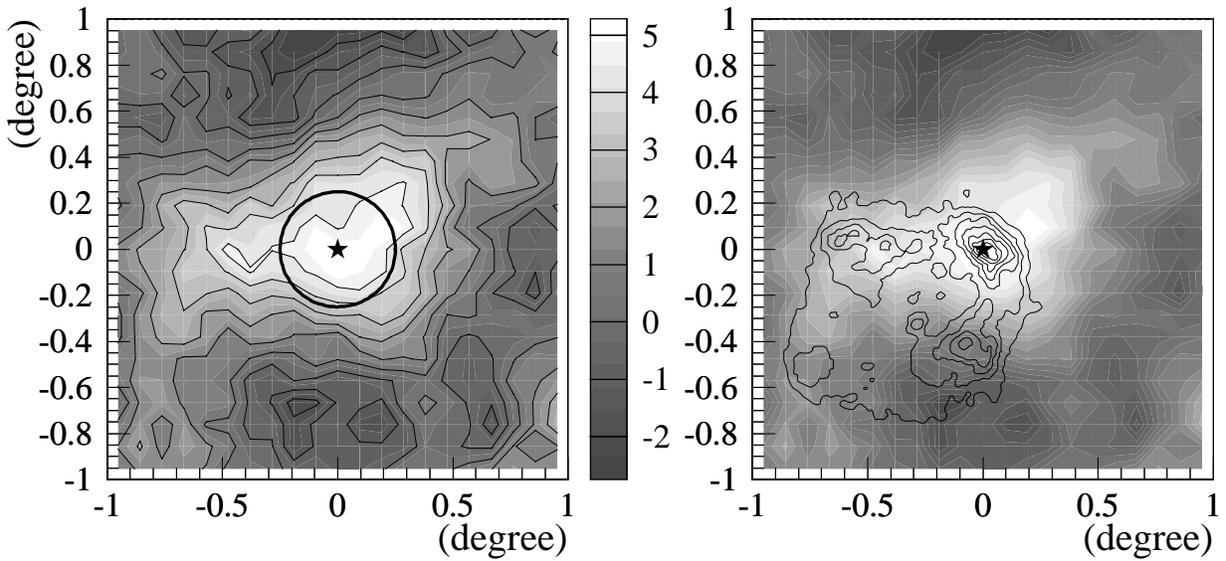

Figure 2: Contour map of the statistical significance around the NW rim of RX J1713.7−3946 plotted as a function of right ascension and declination; north is up, and east is to the left. The contours of the hard X-ray flux also are overlaid as solid lines (Tomida 1999) in the right-hand figure. The solid circle in the left figure is the area of the PSF of the CANGAROO telescope assuming alpha ≤ 20°.