Test by JANZOS of the Standard Model of Cosmic Ray Acceleration in the COMPTEL/ROSAT Supernova Remnant

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Abstract

A search for ultra-high energy gamma-rays emitted by the young, nearby supernova remnant that was discovered recently by the COMPTEL and ROSAT satellites was made using the JANZOS database for the period 1987-1993. A 95% confidence upper limit on the flux above 100 TeV of $3 \times 10^{-13} cm^{-2} sec^{-1}$ was obtained. This is an order of magnitude below the expected flux based on the standard model of cosmic ray acceleration in supernova shocks. An optical survey of the region that has been commenced is also reported. This uses UK and ESO Schmidt plates, and CCD images by a NZ/Japan microlensing group.

1   Introduction:

The supernova remnant (SNR) that was found recently by the COMPTEL and ROSAT satellites (GRO0852-4642/RXJ0852.0-4622) (Aschenbach et al. 1998 and Iyudin et al. 1998) provides an excellent opportunity to test the standard model of cosmic ray acceleration in supernova shocks. This is because the SNR is very close, ~ 200 pc, and at an optimal age for cosmic ray acceleration, ~ 680 years.

Cosmic ray acceleration at the SNR is expected to be accompanied by the production of gamma-rays through interactions of the cosmic rays with the local swept-up interstellar medium. The gamma-rays may be used as a tracer of the cosmic rays. The expected flux of gamma-rays at Earth with energies greater than 100 TeV is $\sim$few$\times 10^{-12}$ cm^{-2}sec^{-1} (Naito and Takahara 1994, Drury et al 1994). Such a flux is easily detectable with current technology. We have examined the database of the JANZOS air shower array at energies >100 TeV. This array was situated at the appropriate latitude for the COMPTEL/ROSAT SNR and was operational from 1987 to 1995 (Bond et al 1988, Allen et al 1993, Allen et al 1995). We report here our results for the period 1987-1993.

We also report an optical study of the region using UK and ESO Schmidt plates and CCD images obtained by the MOA gravitational microlensing collaboration (Abe et al 1996, Alcock et al 1997,

Reid et al 1998, Yock 1998, Abe et al 1999, Yanagisawa et al 1999, Rhie et al 1999, Muraki et al 1999).

2 Experiment:

The data were obtained with an array of 45 fast timing scintillation detectors of area 0.5m^2 that were deployed from 1987 to 1995 over an area 90m ×90m in the Black Birch range in NZ at latitude 42°S and altitude 1640m. A detailed description of the detection system is seen in Bond et al (1988) and Allen et al (1993). It has been found that, for showers with 10~19 timing measurements, 70% had the zenith correctly determined to within ±0.90°. A similar result was obtained in the azimuthal direction. And for showers with ≥ 20 timing measurements the accuracy was found to be better. This accuracy has been confirmed by observations of the cosmic ray shadows cast by both the sun and the moon (Allen et al 1995).

3 Result:

The distribution of air shower events recorded by the JANZOS array close to SNR GRO0852 /RXJ0852.0-4622 from 1987 to 1993 is shown in Figure 1. The diameter of the X-ray image of the SNR is about 2°, and the bin size is 1° × 1°. The distribution includes air showers produced by both cosmic rays and gamma-rays. The former are known to be much more numerous, and to have a nearly isotropic arrival distribution at Earth, because they are charged particles and deflected by the Galactic magnetic field. The observed data are consistent with this, the apparent dependence on declination being an air-mass effect. No clear evidence for an excess of gamma-rays in the direction
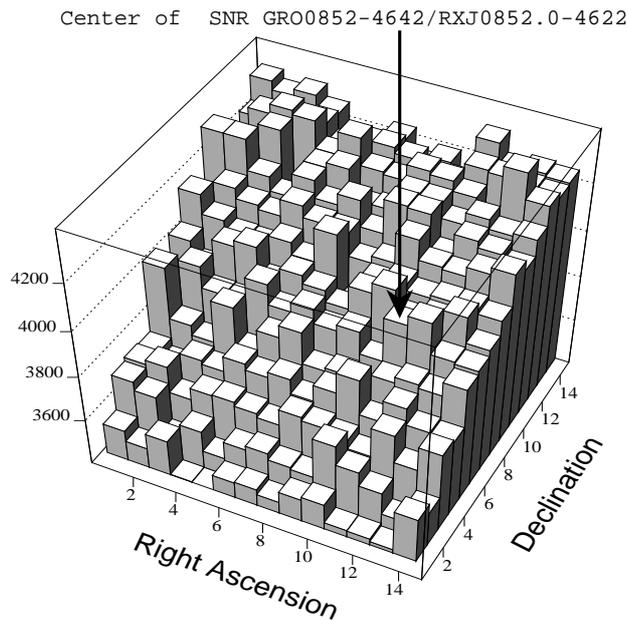

Figure 1: Distribution of air showers detected by the JANZOS array near the COMPTEL/ROSAT SNR (GRO0852-4642/RXJ0852.0-4622). The boundaries are at 118.°58 and 138.°41 in right ascension, and at −52.°00 and −38.°00 in declination. The bin size is 1° × 1°. The diameter of the X-ray image of the SNR is about 2°. The significance of the excess in the direction of the SNR is +0.9 σ.

of the SNR is seen. To quantify this, the distribution of events in a strip of width $2°$ in declination and length $23°$ in right ascension centered on the SNR was examined. The significance of the excess in the direction of the SNR was found to correspond to $+0.9 \sigma$ using Li-Ma statistics (Li and Ma 1983). A similar result was obtained using them constant zenith angle technique of Acharya et al (1990).

The effective detection time and area were 3×10^7 sec and 1.0×10^4 m^2 respectively, and the 95% confidence upper limit on the flux of gamma-rays with energies >100 TeV is 3×10^{-13}cm^{-2}s^{-1}. These values are given in Table 1. The measured upper limit is an order of magnitude below the expected flux cited in Section 1.

Table 1. Result on the flux of gamma-rays from SNR GRO0852-4642/RXJ0852.0-4622

Mode energy (TeV)	Events in SNR bin($2° \times 3°$)	Background in strip bin($2° \times 20°$)	Excess (Li-Ma) (σ)	Flux upper Limit (95% conf. level) ($\times 10^{-13} cm^{-2} s^{-1}$)
100	23,622	156,464	+ 0.9	3.0

4   Optical Observations:

Apparently there is no historical record of the COMPTEL/ROSAT SNR, even though a supernova approximately 250 pc away might be expected to outshine the full moon. We have commenced an examination of ESO and UK Schmidt plates in the R, J, SR and I passbands, but see no obvious nebulosity that matches the ring-like X-ray image of the SNR.

We have also taken several exposures in broad red and blue passbands of the region using a wide-field Boller & Chivens telescope at the Mt John University Observatory in NZ, and a large CCD camera of the MOA collaboration referred to in the Introduction. These exposures are currently being stacked to yield images that are expected to have limiting magnitudes fainter than 22. The image below is a preliminary stacked image in the red passband of a region covering ~ 0.5 square

Figure 2: Optical image in red light of 0.5 square degree near the northern rim of the COMPTEL/ROSAT SNR. The image extends from $-46°45'$ to $-47°15'$ in declination (2000), and from 8h 50m to 8h 54m in RA. The black and white intensity limits are approximately equal to the minimum and maximum intensities of nebulosity. The limiting magnitude is ~ 22.

degree near the northern rim of the SNR. Some nebulosity is seen in this image, and it matches the nebulosity in the Schmidt plates. It has, however, been rendered clearer than the nebulosity seen in the Schmidt plates by judicious use of the grey scale limits. It is not yet known if the nebulosity is caused by the COMPTEL/ROSAT SNR or by other phenomena. It is hoped that, when further CCD images become available that cover the entire SNR, the cause of the nebulosity will become clearer.

5 Discussion:

Despite being discovered in 1912, the origin of cosmic rays has not yet been discovered. It is generally assumed that cosmic rays with energies up to about 10^{15} eV are accelerated in the shocks of supernova remnants by the Fermi mechanism, but this has not been confirmed (Yock 1998, Normille 1999). Unfortunately, the present study has also failed to provide confirmation. The measured flux of gamma-rays from the COMPTEL/ROSAT SNR is at least an order of magnitude less than the prediction. The apparent disagreement between observation and theory may be indicative of an anomaly of the supernova that caused the COMPTEL/ROSAT SNR, or of the interstellar medium in which it exploded (Chen and Gehrels 1999).

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