Search for VHE gamma ray emission from SNRs with the data of Tibet AS$_\gamma$ III

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Abstract

The paper discusses some preliminary results about gamma ray emission from some of SNRs by analysing the data of Tibet AS$_\gamma$ III. The equi-zenith angle method and Right Ascension scan with livetime correction are used. The significance derived from t test for the results is discussed.

1. Introduction

It is quite successful for ACTs (Atmospheric Cherenkov Telescopes) to search for VHE gamma ray emission.In 1989 Whipple collaboration observed gamma ray emission from Crab Nebula with the help of gamma-proton discrimination[1].The fact has established Crab Nebula as a standard candle of VHE gamma ray emission.In 1995 and in 1996 Cangaroo collaboration observed steady gamma ray emission from PSR1706-44 and Vela in the same way.In 1992 and in 1995 Whipple group first detected VHE gamma ray signal from Mrk 421 and Mrk 501,which are Active Galactic Nuclei. So far 6 gamma ray point sources in VHE were observed,namely Crab nebula, PSR1706-44,Vela,GRS1915+10 in the Milky Way and Mrk 421,Mrk 501 outside of our galaxy.

EAS array is also an effective method for observation of VHE gamma ray emission. But most results given by EAS array are negative because of low signal to noise ratio in VHE region. Tibet AS$_\gamma$ experiment is the Sino-Japan cooperative experiment,located at Yangbajing,Tibet, which has been running for more than 10 years. The array has shown some promising results. In 2000 gamma ray emission in 4.8 σ from Crab Nebula and a high state of 6.9σ from Mrk 421 were observed with the data of Tibet AS$_\gamma$ III [2].

2. Data analysis

Until now two kinds of methods are often used to search for a gamma ray point source. One is Right Ascension Scan(RAS) and the other is Equi-Zenith Angle method.(EZA).These two methods are different in background estimation. For RAS method the background events are taken from the mean value of other RA windows in the same declination band as the source.So it is necessary to have

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live time correction because the source and background windows reach the same zenith angle bin one by one at different time. For EZA method the background is estimated from the mean value of other azimuthal windows at the same zenith angle and in the same time duration. However a uniform azimuthal distribution is required. The signal significance of source window can be calculated by the formula below,

$$s = \frac{N_{on} - \alpha N_{off}}{\sqrt{N_{on} + \alpha^2 N_{off}}}$$

where N$_{on}$, N$_{off}$ stand for the number of showers from the source and background windowns respectively, $\alpha = t_{on}/t_{off}$ the ratio of source observation time to background ones . If the number of showers from the source window is less than 20, Li-Ma formula is used,[3]

$$s = \sqrt{2}\ \{\ N_{on}\ ln\ [\ \frac{1+\alpha}{\alpha}(\frac{N_{on}}{N_{on}+N_{off}})\ ]\ + N_{off}\ ln\ [\ (1+\alpha)(\frac{N_{off}}{N_{on}+N_{off}})\ ]\ \}^{1/2}.$$

In this work the total observed shower events are divided into 10 groups by shower size $\sum \rho_{FT}$,(which corresponds to different primary energies). Each group contains nearly equal number of shower events. The angular resolution can be expressed as the function of $\sum \rho_{FT}$[4],

$$\Delta\theta(\sum \rho_{FT}) = (0.63 \pm 0.02) \times (\sum \rho_{FT}/100)^{(-0.54\pm0.04)}$$

Table 1. Different angular radius for different shower size or primary energy

$\sum \rho_{FT}$	energy band (in TeV)	angle resolution (^{o})	$\sum \rho_{FT}$	energy band (in TeV)	angle resolution(^{o})
15-20	2.09-2.75	1.3	39-48	5.19-6.32	0.8
20-24	2.75-3.27	1.2	48-62	6.32-8.06	0.7
24-28	3.27-3.79	1.1	62-83	8.06-10.6	0.6
28-33	3.79-4.43	1.0	83-134	10.6-16.8	0.5
33-39	4.43-5.19	0.9	134-500	10.7-58.6	0.4

Firstly, significances for source window are calculated for all energy bands and then the student variable t is used to estimate the significance,

$$t = \frac{\mu - \bar{s}}{S_{\bar{s}}}, \qquad \mu = 0, \qquad \bar{s} = \frac{\sum_{i=1}^{n} s_i}{n}, \qquad S_{\bar{s}}^2 \equiv \frac{S_s^2}{n} = \frac{\overline{s^2} - \bar{s}^2}{n-1},$$

$p(t) \sim t(t;\nu)$, t distribution with DOF= ν = n-1.

$p(t) \sim n(t;0,1)$ if $\nu >> 1$.

3. Gamma ray emission from SNRs

The data used in the work was taken from November 1999 to September 2002 by Tibet AS$_\gamma$ III. There were about 9×10^9 shower events recorded. The threshold energy of observed air shower is estimated to be 1.5 TeV for protons. The angular resolution is about 0.87^o above 3 TeV with the Monte Carlo simulation and confirmed by the moon shadow of cosmic rays[4].

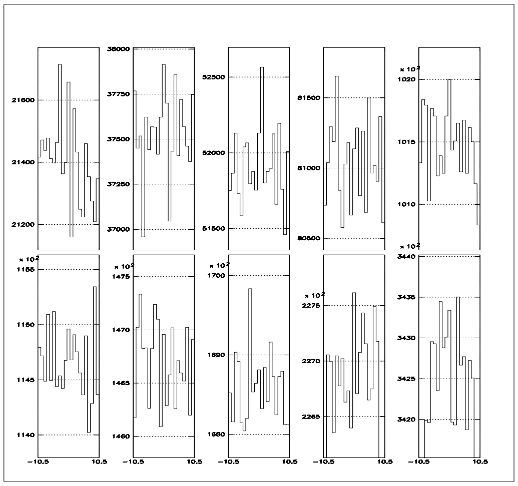

Fig. 1. Event distribution for 10 energy bands. the middle bin is for Carb Nebula

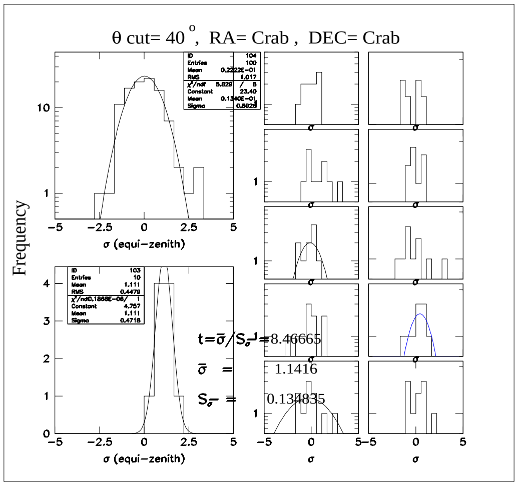

Fig. 2. Significance distribution for Crab Nebula (lower left) and 10 supposed sources(at right).

The event selection criteria are as follows: zenith angle is less than 40 degree, residual error in reconstruction of shower direction is less than 1 m and the shower core position is inside the array. According to the angular resolution listed in Table 1, the searching for gamma ray emission from a SNRs are carried out at 10 energy bands,respectively,with various window size. For one source window, 10 background windows which locate symmetrically at both sides of the source are used. Also any of 10 background windows is regarded as a supposed source and their excess significances are also calculated.

As an example fig.1 shows how shower events change with azimuthal windows, in which the middle one is the number of showers from Crab Nebula. 10 subplots correspond to 10 energy bands. From the subplot at the lower left of Fig.2, the mean significance distribution from 10 energy bands for Crab Nebula is $\bar{s}$ =1.14σ and t=8.5 for DOF=9. The subplot at the upper left of Fig.2 is significance distribution from 10 energy bands for 10 supposed sources. It is seen the distribution is a Gaussian one around the mean $\mu = 0$ with variance = 1. It indicates that the shower events from Crab Nebula has at least 3.6σ excess. 10 subplots at the right are significance distributions of 10 energy bands for every supposed sources, among which no large t value can be found.

Also we analysed gamma ray emission using same methods from other 10 shell-type SNRs each with distance less than 5kpc.The results are listed in Table 2.Neither significant $\bar{s}$ nor large t is found.

Table 2. Sinificance for gamma ray emission from SNRs

Position (Name)	EZA		RAS	
hh mm ss dd mm	$\bar{s}$	t	$\bar{s}$	t
Crab Nebula	1.14	8.4	1.05	5.4
18 56 00 +01 22	0.30	0.51	0.09	0.17
19 33 20 +18 56	0.68	2.77	0.69	2.67
20 20 50 +40 26	0.51	1.86	1.04	4.01
20 19 00 +45 30	-0.12	-1.52	0.09	0.25
21 29 20 +50 50	-0.35	-0.20	-0.37	-1.65
21 24 50 +51 53	-0.05	-0.20	-0.37	-1.65
23 01 35 +58 53	-0.34	-1.42	0.34	1.44
23 23 26 +58 48	-0.25	-1.15	-0.18	-0.99
23 37 00 +61 55	-0.39	-1.47	-0.27	-1.09

4. Conclusions

(1) The showers from Crab Nebula have at least 3.6σ excess. However with t test, the t = 8.4 or 5.4 is far away from the expected value of 0. The probability is very small for about 1.14 σ excess in each of 10 energy bands at the same observed duration. An exact significance estimation will be checked by MC.

(2) No gamma ray emission are observed from other shell-type SNRs.

5. Acknowledge

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6. References

[1] Week T.c.,et al., ApJ Vol.342(1989)379.
[2] Amenomori,M.,et al. Proceeding of ICRC 2001, OG2.2
[3] Ti-pei Li and Yu-Qian Ma, ApJ. Vol.272(1983)317-324.
[4] Amenomori,M.,et al. Proceeding of ICRC 2001, HE124