Search for TeV GRBs using the Tibet-III ASγ Data

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Abstract

Search for TeV GRBs was made by using the ASγ(Tibet-III) data taken from Nov. 1999 to July 2002. A GRB candidate was chosen as a shower cluster appearing in a given small sky window and a time interval ranging from 1 to 100 seconds. An equi-zenith-angle method was used to estimate the background. In this analysis,two methods searching for possible GRB's signals independently and searching for possible burst-like events coincident with satellite GRB data have been applied. No significant TeV gamma-ray bursts were detected.

1. Introduction

Gamma-ray bursts(GRBs),appearing at an unpredictable time from unpredictable directions in the sky,are still one of the most mysterious astronomical phenomenon though more than 30 years have passed since their discovery.The results of BATSE GRBs showed that the angular distribution of GRBs on the sky is highly isotropic[1] and the afterglows measurements of GRBs show that at least some long GRBs origin from cosmological distances[2].

It is very important to detect VHE GRBs because these photons would be strongly attenuated by infrared background photons and microwave background radiation photons when traveling cosmological distances. Several experiments have devoted to search for VHE GRBs,but all reported negative results.

2. Experiment

The ASγ experiment located at Yangbajing in Tibet(4,300m a.s.l.) and the performance of the Tibet-III array are described elseswhere [3].The threshold energy is about 1.5TeV for protons and the angular resolution is estimated to be better than 0.9^o on average which can be extracted from the measurement of Moon shadow.The analysed data were taken from Nov. 1999 to July 2002.The total effective running time was about 530.9 days and 1.45×10^{10} events were selected after requiring the zenith angle less than 50^o.

3. Data Analysis

In this work,two methods were used.One is to perform a general search independent of the satellite GRBs data.While the other is to search for TeV burst-

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like events coincident with the GRBs detected by satellite experiments. Within the period we analysed,there were 25 BATSE GRBs and 8 other satellites GRBs in the field view of Tibet(with the zenith angle less than 50^o).

For general search,each event was chosen as the center of an angular bin(on-source window) and was treated as the begining of a candidate GRB. For each BATSE GRB,a circular search region was defined by the BATSE 90% confidence level positioning error(statistical and systematical)[4].The on-source window was chosen in this search region,by shifting every 0.5^o in right ascension and declination plane.As for the 8 GRBs detected by other satellites from GRB network [5],their positions are determined with a precision much better than the angular resolution of Tibet-III ASγ experiment.In this case,the on-source window was centered at the position reported by satellite experiment.

Non(hereafter we call it the multiplicity),which is the number of events falling within the on-source window and a time interval,was counted and compared with the number of background events to estimate the significance.The "equi-zenith-angle method" is used to estimate the background rate$\langle Nb \rangle$ which is averaged by 10 off-source windows(same size as on-source window) in the azimuthal directions with the same zenith angle.In this work,the angular radius 0.9^o of on-source window was chosen.The time intervals of 1s,10s,20s,50s,100s were tried in general search.While in coincidental search,the time intervals of 1s,5s,10s,15s,20s,40s,60s,90s,100s starting from the BATSE GRB trigger time for 25 BATSE GRBs and starting from 1000s before to 1000s after satellite GRB trigger time with the time step chosen as 1s for 8 other satellites GRBs were tried.

A probability(P_{bkg}) of this candidate being due to a background fluctuation can be calculated as:

$$P_{bkg} = \frac{1}{2}P(Non) + \sum_{i=Non+1}^{\infty} P(i) \qquad (1)$$

Where $P(i)$ is the Poisson probability for the observed multiplicity(i).The lower the P_{bkg},the more a GRB likes.

4. Results

Fig. 1 shows the distributions of P_{bkg} which were calculated by (1) for all candidate clusters at different time intervals in general search.The P_{bkg} of six shower clusters are seen to be less than 10^{-10}.Table 1 contains the detailed information of these six candidate GRBs. As the number of trials is about 1.45×10^{10}, no GRBs can be declared after taking this into account.

Fig. 2(a) shows the distribution of P_{bkg} for all clusters coincident with 25 BATSE GRBs.The lowest probability is related with GRB000313 whose position determined by BATSE is (α,δ)=(197.89^o,10.25^o).The circular radius of 90% confidence level is about 11.4^o.The cluster with the largest excess found in ASγ

experiment was centered at (α,δ)=(195.39^o,9.75^o) corresponding to a zenith angle of 31^o.It was 2.5^o away from the position reported by BATSE.This cluster contains 20 air shower events in 40s ,while the expected number of background events is 4.68.Then P_{bkg} was calculated to be 7.58×10^{-8}. There is no significant signal after considering the number of trials(1.5×10^4).Fig. 2(b) shows the lightcurve where the events are bined in 40s.Before and after BATSE GRB trigger time,the burst-like events were also searched, no significant events were found.

Fig. 3 are the P_{bkg} distributions for all clusters coincident with 8 other satellites GRBs.One of clusters in GRB991208 shows a lowest P_{bkg}(about 1.6×10^{-6}) which was found 928s after satellite GRB trigger time in 90s. Fig. 4 is the lightcurve of GRB991208 in ASγ data.

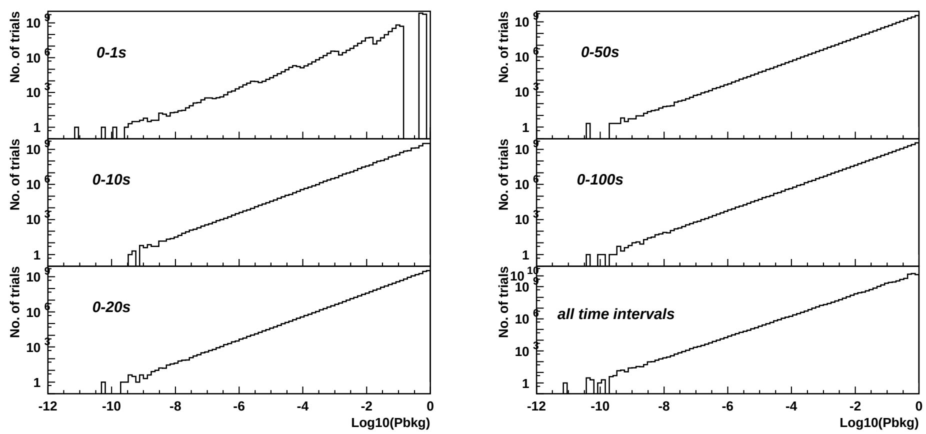

Fig. 1. P_{bkg} distributions for 5 time intervals and the last one combines all

Table 1. the detailed information of six candidate GRBs

Name	Non	$\langle Nb\rangle$	MJD	$\theta(^o)$	$\alpha(^o)$	$\delta(^o)$	$P_{bkg}(10^{-11})$	Δt(s)
A	8	0.17	51608.01674	23.94	233.28	24.68	0.72	1
B	59	22.03	51894.62620	11.94	29.30	25.05	3.62	100
C	55	20.17	52001.79855	15.54	197.88	18.45	8.29	100
D	14	1.27	52002.53228	38.14	72.67	21.21	5.41	20
E	28	6.01	52026.65339	29.03	192.72	3.11	3.93	50
F	36	9.64	52412.52814	19.08	168.35	14.34	4.76	50

5. Conclusion

We have searched for TeV GRBs using Tibet-III ASγ data by two methods.After considering the number of trials,the chance probability will be about 10^{-2} in general search and 10^{-3} in coincidental search.So no significant signals of TeV GRBs can be claimed.The flux upper limit at 95% CL was estimated to be $10^{-9} \sim 10^{-7}$ph.cm^{-2}.s^{-1} for an assumed E^{-2} spectrum above 1TeV without considering the infrared absorption.

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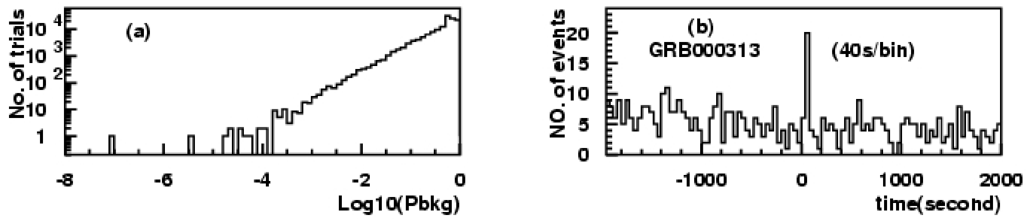

Fig. 2. (a) is the P_{bkg} distribution for 25 BATSE GRBs and (b) is the lightcurve of GRB000313 in ASγ data

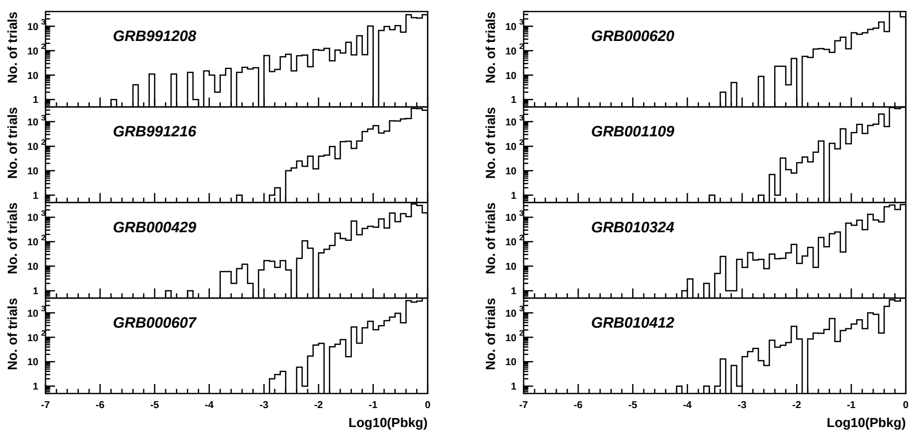

Fig. 3. The P_{bkg} distributions for 8 GRBs

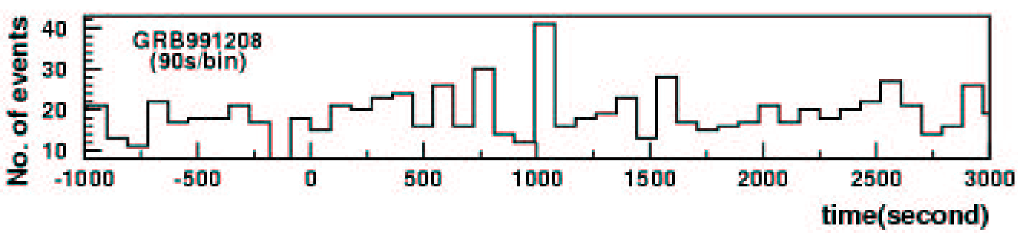

Fig. 4. The lightcurve of GRB991208 in ASγ data.

6. References

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