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Gamma Rays of Energy $\gtrsim 10^{15}$eV from Cyg X-3

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ABSTRACT

The experimental data of extensive air showers observed at Akeno have been analyzed to detect the gamma ray signal from Cyg X-3. After muon-poor air showers are selected, the correlation of data acquisition time with 4.8 hours X-ray period is studied, giving the data concentration near the phase 0.6, the time of X-ray maximum. The probability that uniform backgrounds create the observed distribution is 0.2%. The time-averaged integral gamma ray flux is estimated as $(1.1\pm0.4)\times10^{-14}$cm^{-2}sec^{-1} for Eo>$10^{15}$eV and $(8.8\pm5.0)\times10^{-14}$cm^{-2}sec^{-1} for Eo>$6\times10^{14}$eV.

1. Introduction

In the energy region larger than 10^{15}eV (PeV), Samorski and Stamm presented in 1983a and b the first evidence from Cyg X-3. The result is then supported by Lloyd-Evans et al. 1983. They have shown that the PeV signals are concentrated around the phase of 0.3 where the phase zero corresponds to the minimum intensity of 4.8 hours variation of X-ray. The present paper reports another evidence on the positive detection of PeV gamma rays from Cyg X-3. The data are from EAS observation at EAS Array at Akeno during 1981 and 1984.

2. Experimental arrangement

EAS Array at Akeno(Hara et al. 1979) consists of 201 scintillation counters of 1m^2 area and nine muon(threshold energy is 1 GeV) detectors of 25 m^2 each. The data recorded by the trigger for small size EAS are used for the analysis. The region within the circle of 30 m radius near the center of the array is taken as the detection area of the EAS cores. This local trigger(called common trigger hereafter in this paper) for small EAS, of which threshold is about 1 PeV, is available since 1981 with stable operation conditions and with almost full utilization of nine muon detectors. The data observed from the beginning of 1981 to September 1984 are dealt with in the present paper. Twenty nine fast timing detectors are equipped with near the central part of the array for most of the observation period, giving about 3 degree of resolution in the arrival direction(Ishikawa et al. 1981). In order to get the events for the lower gamma ray energy, a temporal high rate trigger(called temporal trigger) was executed in 1984 only when Cyg X-3 is near the meridian passage. The threshold energy is about 1 PeV.

3. Analysis of observed data

Selected as candidates for Cyg X-3 signals are the events from the field of view defined by $\pm 10^{\circ} X \pm 10^{\circ}$ square area of the sky around right ascension 307.6° and declination 40.7°. The data observed exactly within one period 4.8 hours of X-ray variation per day are used for the analysis to exclude interference effects between the period and the observation time.

For each selected event, the ratio, $R = N_{\mu}/Ne$, is used to select the data in favour of gamma rays against normal showers originated by nuclear active particles. The mean of the total(normal) showers is about R=0.03 and the cut of the data is set at R=0.001.

Eighteen events have remained after the selection criteria described above for the common trigger. These events are then checked if they are correlated with the 4.8 hours periodical variation. The non-uniformity of the data against the phase of 4.8 hours period is tested by the so called Rayleigh test, as is also used by Dowthwaite et al. 1982. In the test, each event is represented by a unit vector in a 2-dimensional space where the azimuthal angle corresponds to the phase. The norm of the summed vector over all the events gives the measure of non-uniformity. The amplitude, a, of the non-uniformity, the norm divided by the number of events N, is then compared with the expected value from the random walk. The statistical reliability of the apparent non-uniformity is expressed by the parameter $k=Na^2/4$, where the probability of uniform distribution producing the observed one is given by exp(-k)(see for example Linsley 1975).

4. Results and Discussions

The number of observed events is plotted in figure 1a as a function of the phase of 4.8 hours variation, when the period is put 0.1996854 day as the one by van der Klis and Bonnet-Bidaud 1981. The phase zero is defined as the time of the minimum intensity of X-ray. The distribution shown in figure 1a gives the value k = 6.2. The probability that a uniform distribution produces the observed one is 0.2%. The analyses are done with various values of test period p to see if the non-uniformity occurs synchronized exactly with the X-ray period. The result is shown in figure 2. The tested periods cover a wide range of 0.1995 to 0.1999 day and the highest value of k is obtained at the periods X-ray data predict. The periods given by

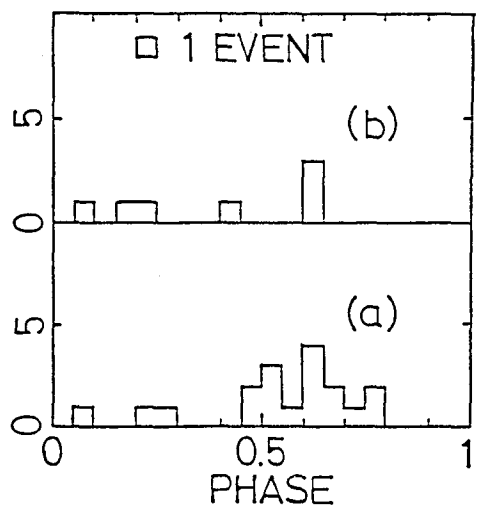

figure 1. The number of events plotted against phase of 4.8 hrs variation. (a) common trigger (b) temporal trigger

Parsignault et al. 1981 and van der Klis and Bonnet-Bidaud 1981 are shown by arrows in the figure. Another high value of k appears around p = 0.19975. This side peak can be understood as the second best fit which is created by a combined effect of the synchronization at the X-ray period and the data of the largest interval of acquisition time.

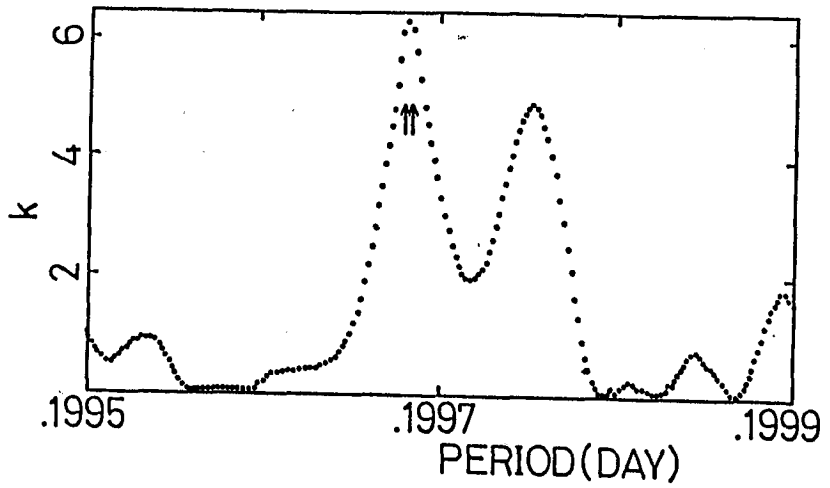

figure 2. The parameter k of statistical significance of non-uniformity is plotted against the test period

The off-source data selected by the same criteria for on-source both in the field of view and in N_μ/Ne cut are also analyzed to get the spurious correlation with the X-ray period. The parameter k of non-uniformity are plotted in figure 3a as a function of right ascension, where the off-source directions are defined. Declination is set between 30.7° and 50.7°. The off-source data sets give no larger non-uniformity than the on-source data set. In figure 3b, the integral spectrum of k is plotted. The k-spectrum is well explained by the statistical fluctuation, which is given by the function exp(-k) (straight line in the figure normalized by the total number of the data sets for different directions in the sky), except the largest value 6.2 for the on-source data set.

The number of data in the temporal trigger is too small to get a statistically meaningful arguments. The distribution versus phase is, however, consistent as is shown in figure 1b with the result by the common trigger.

Our data confirm the conventional view that the gamma ray EAS has a poor containment of muon, on the contrary to the result by Samorski and Stamm 1983c. While, the data cut by shower age after Kiel group produces no significant result(k=0.6). This may suggest that our trigger for data recording is biased in small Ne region, inefficient to flat EAS's of old shower age initiated by gamma rays.

The other kind of systematic errors arises from the ambiguity in data cut by N_μ/Ne. The result for the loose cut in N_μ/Ne smaller than 0.003 and 0.01 results in the concentration of events at the phase near 0.6 is observed with less significance of k=2.4 and 1.6, respectively. The number of counts around ϕ =0.6 exceeds the average by 16 and 28, respectively. If these excess is attributed to the signal, the obtained flux could be at most doubled. In figure 1a, the extraction of seven events at phase 0.6 results in k=1.0, which may indicate that about 7 events could be attributed to the signal.

The integral flux is obtained as $(1.1\pm0.4)\times10^{-14}cm^{-2}sec^{-1}$ for $Eo>10^{15}eV$ and $(8.8\pm3.8)\times10^{-14}cm^{-2}sec^{-1}$ for $Eo>6\times10^{14}eV$, by taking 7 and 3 events near 0.6 phase in figure 1a and b as the signals and by correcting for the inefficiency due to the trigger bias. The given errors are the statistical errors and the systematic errors can allow larger fluxes than the quoted ones.

The preceding results of Kiel and Haverah Park have a sharp peak at the phase 0.3, while the present result shows a broader one near the phase of 0.6 at the X-ray maximum intensity rather coincident with $10^{12}eV$ results.

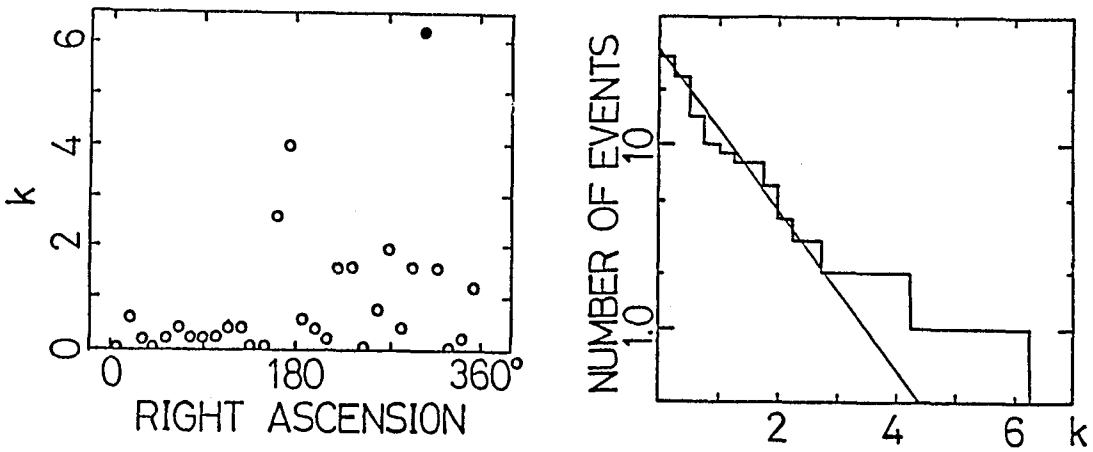

figure 3. (a) The parameter k is plotted for the data sets from various direction of the sky. (b) Integral spectrum

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