An Analysis of a Candedate of Non-Random Component in Extensive Air Showers above 0.1PeV

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Since the summer in 1989, although there were deficits of observations for some weeks because of a moving of our institute, we have been looking for astrophysical bursts over time scales ranging from several milliseconds to seconds by operating small groups of scintillation counters in flexible trigger mode and a time resolution of a few milliseconds. The systems of data acquisition and of scintillation counters are performed by using a CAMAC electronics[1]. These systems have been published in the other papers[2]. For checking complete operations of all the systems, distributions of the shower size, the zenith angle and the position map of incident directions in the sky co-ordinate have been studied. Their distributions and the map are shown in Fig.1, Fig.2 and Fig.3, respectively. These distributions are not contradict with the other experimental results of air showers with energies of > 0.1 PeV so far observed. Also the map shows to have a uniform distribution, which has been confirmed by showing uniformly by means of the spherical statistical test.

Up to the present observations, no positive candidates have been found of bursts lasting over the time scales of several milliseconds to several seconds. In contrast with such the bursts, one event of a random temporal sequence of 14 events within 10 min time interval was observed throughout the time of 10:55 to 11:05 (JST) on 21st of June 1990 for about 3 months data which includes 38,833 showers, during total observations of 110,000 shower triggers over 16 months period. The air shower detection rate for the data run in question was (0.287 ± 0.053) $\mathrm{min}^{-1}(= 108,416evt/6,297.9\mathrm{hrs})$, excluding this burst event. A distribution of the numbers of events of air showers from 18th June to 13th September 1990 is shown in Fig.4 and listed in Table 1. As seen from the figure a occurrence rate of one burst event is large deviated from a occurred frequency of 0.061 with 14 events which is expected from the Poisson distribution, we shall discuss about the burst event by using the following statistical tested methods.

a) the chi-square χ^2 test of distribution: An observation data around an occurred time of the candidate event, the data being from 09:55 to 12:55, are subdivided by a certain time interval of 10 min. The candidate event is between 10:55 and 11:05. The starting time being shifted seconds by seconds, the region of observation data is adopted by the highest significant case in χ^2 test.

$$\chi^2 = \sum_{i=1}^{16} \frac{(n_i - e_i)^2}{e_i} = 45.60,$$

where the expected frequency: $e_i = (1/18)\sum_i n_i = 3.722$, n_i is the number of observed events in the i-th 10 min division. This corresponds to the probability that a real cluster exists with the confidence level 99.99% for a degree of freedom $n_D = 18-2 = 16$.

b) An upper limit of the probability for the Chebyshev's inequality expression:

The probability for observing any specific number of counts is given by the Poisson distribution with a mean of x_0 and a standard deviation σ. According to Chebyshev's theorem, then, an upper limit can be set for the probability that the occurrence frequency of the candidate events will exceed kx as follows,

$$Prob(|x - x_0| \geq k\sigma) \leq 1/k^2.$$

For the same observation data as treated in a), we shall apply this method. Defining the mean x_0, the dispersion m and the standard deviation of the Poisson distribution, $x_0 = m = \sigma^2$ stands. Then,

$$x_0 = m = 3.30 = \sigma^2$$

for the data in 09:55 - 12:55.

$$\sigma = \sqrt{m} = 1.79, k\sigma = 14 \text{ events},$$

therefore $k = 7.82$. Accordingly,

$$Prob(|x - x_0|) > 14) = (1/7.82)^2 = 0.016.$$

This corresponds to the significance level of 1.6%.

c) An adaptive cluster method:

Buccheri et al.[3)] have used this method to search for short bursts of gamma-ray emission of up to thousand seconds duration from the source. In the method, the data of arrival times of the air showers are subdivided by a cluster (a certain time interval). So, the cumulative Poisson distribution is calculated about all the clusters. In a case of all observing time, T, and all number of the events, N, we can compute the probability for chance occurrence P_1 in which the events having above n number arrive onto the detector, as follows

$$P_1 = 1 - \exp(-Nt/T) \sum_{r=0}^{n-1} [(Nt/T)^r / r!].$$

Next, we get a product of $P_1 \cdot M$ (where M is the number of clusters analyzed). When the value of $P_1 \cdot M$ is smaller than 0.01, an existence of the event of candidate can establish with the significance level of 1%. We apply this method for a part of a observation data of 2000 events in 3.8×10^5 sec which has been analyzed. In Fig.5, a relation between the time width of the cluster and the threshold number of the real burst (which can give $P_1 < 0.01$) is shown in the case of $T = 3.8 \times 10^5$ sec and $N = 2000$ events of air showers analyzed by this method.

Table 2 gives calculated values of P_1 for n number in the different time width of the cluster for the present analyzed data. From the table, a case of $n = 14$ events in the time width $t = 600$ sec is the probability for smallest chance occurrence $P_1 \cdot M = 0.000026 \times (381,475/600) = 0.0165$. This value means that the significance level does not exceed 1%.

Although the methods for a) and b) can give the significance level of smaller than 1
At first glance of the data observed during the other time, also, it seems no such candidate events. This means to give the candidate with more decreasing significance level. However, arrival directions of all 14 events of air showers indicate the similar incident directions with one another. The fact endorses the candidate to have higher significance level. It is necessary more careful analysis.

We are now under analyzing for the other data and under discussing validity of these statistical methods, and also continue observing with increasing the number of detectors.

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file name 900618 ev# 1191 to 1261
900621

R.A.	Decl.		
10:00:00			
2.579	25.172		
1.429	7.680		
10:10:00			
4.367	39.849		
5.164	14.385		
1.232	46.752		
4.588	62.470		
4.159	32.290		
10:20:00			
4.392	19.855		
3.935	33.310		
3.682	15.593		
5.212	27.791		
3.204	13.081		
10:30:00			
3.674	16.674		
4.197	41.915		
2.269	28.222		
10:40:00			
2.868	27.131		
4.395	50.724		
4.540	40.400		
2.613	18.188		
10:50:00			
3.055	20.078		
2.713	16.815		
3.658	6.819	1	ev#1212
4.031	40.417	2	
1.121	54.407	3	
3.514	32.174	4	
5.365	29.325	5	
11:00:00			
23.230	73.737	6	
4.824	39.804	7	
6.270	40.418	8	
4.480	8.050	9	
5.874	37.438	10	
1.664	35.579	11	
3.305	33.098	12	
5.483	60.281	13	
4.510	45.663	14	ev#1225
6.581	27.618		
4.386	12.049		
11:10:00			
6.421	38.353		
11:20:00			
4.596	27.334		
2.909	45.065		
11:30:00			
4.127	57.942		
11:40:00			
6.361	34.853		
3.651	29.900		
5.911	61.404		
11:50:00			
7.847	47.529		
3.925	30.550		
6.567	28.242		
5.139	35.949		
12:00:00			
5.009	25.399		
5.343	27.799		
4.070	46.710		
12:10:00			
5.347	44.299		
8.473	52.285		
12:10:00			
2.745	18.729		
4.349	61.583		
6.843	24.284		
12:30:00			
4.405	15.873		
5.555	50.621		
12:40:00			
5.608	30.077		
6.919	56.808		
5.052	13.924		
5.484	14.433		
4.607	50.898		
8.582	57.340		
6.610	51.480		
5.439	49.800		
12:50:00			
4.891	35.879		
5.758	21.192		
5.141	31.947		
3.845	39.372		
13:00:00			

Table 1: Event list of the data from 10:00:00 to 13:00:00(JST) on 21st June 1990. The candidate is comprised in 14 events (the event number 1212 to 1225), from 10:55:00 to 11:05:00(JST).

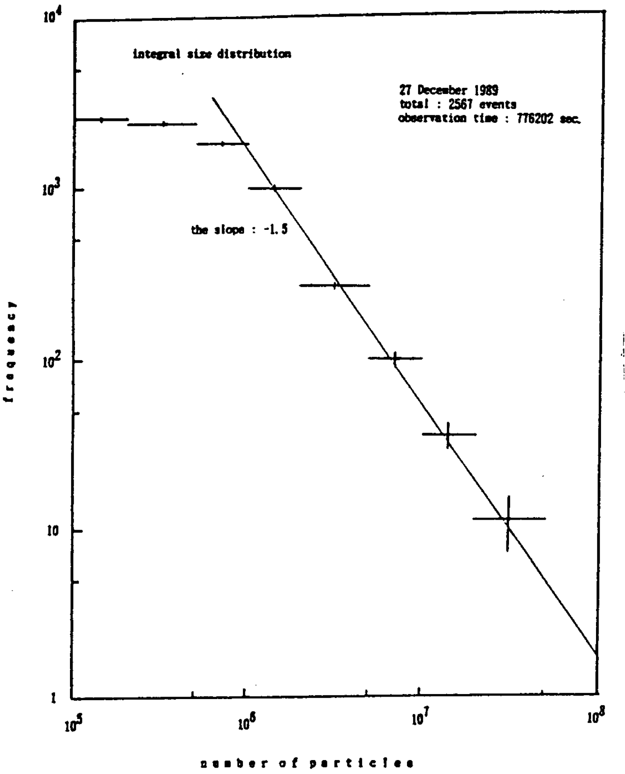

Fig. 1: The distribution of size for observed events. The slope of fit line is 10.3.

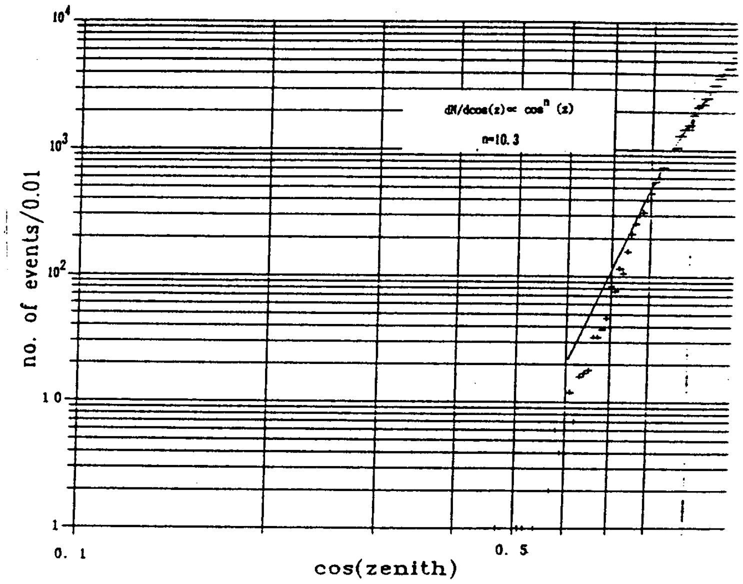

Fig. 2: The distribution of cosine of zenith angle. Power index of the fit line is 10.3.

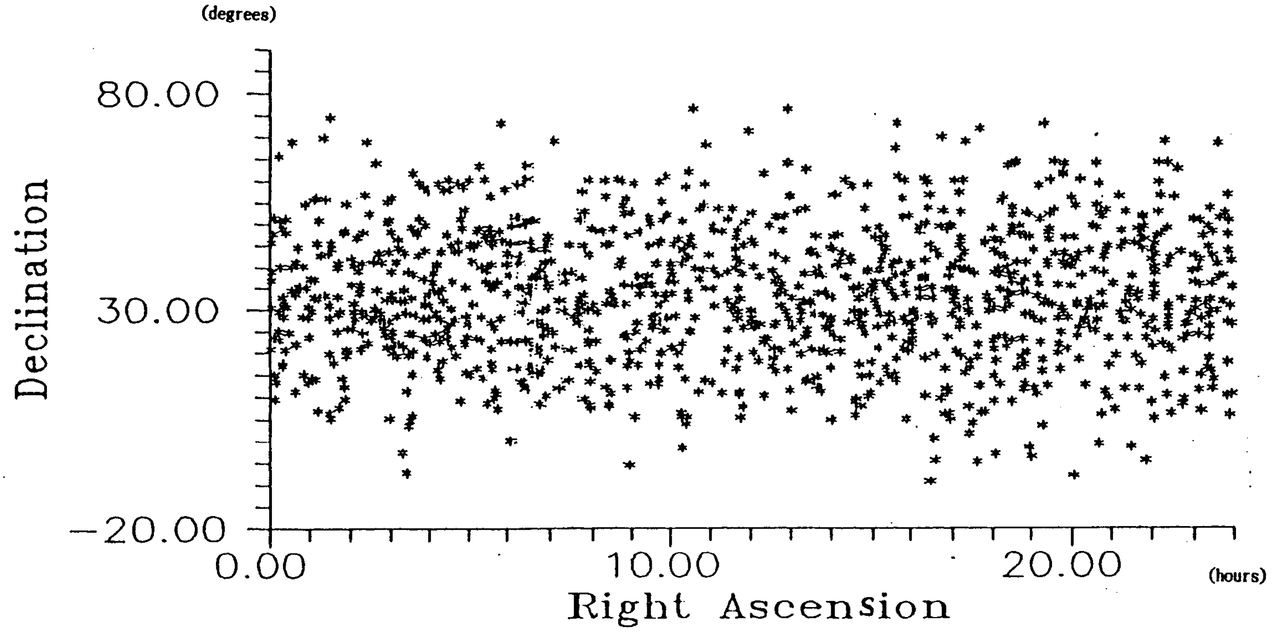

Fig. 3: The direction for arrival EAS's on the celestial coordinate, right ascension and declination.

⟨t = 1200sec⟩		⟨t = 600sec⟩				⟨t = 300sec⟩							
n	P_1	n	P_1	n	P_1	n	P_1	n	P_1	n	P_1	n	P_1
14	0.013	9	0.015	5	0.385	4	0.210	5	0.075	1	1.000	4	0.210
7	0.600	2	0.957	5	0.385	2	0.793	0	1.000	3	0.466	2	0.793
3	0.986	0	1.000	3	0.822	0	1.000	0	1.000	2	0.793	1	1.000
11	0.105	7	0.099	4	0.609	3	0.466	4	0.210	2	0.793	2	0.793
7	0.600	4	0.609	3	0.822	1	1.000	3	0.466	1	1.000	2	0.793
18	0.003	14	0.000026	4	0.609	5	0.075	9	0.00023	3	0.466	1	1.000
2	0.998	2	0.957	0	1.000	0	1.000	2	0.793	0	1.000	0	1.000
4	0.950	3	0.822	1	1.000	1	1.000	2	0.793	1	1.000	0	1.000
8	0.440	6	0.209	2	0.957	4	0.210	2	0.793	1	1.000	1	1.000
6	0.752	4	0.609	2	0.957	1	1.000	3	0.466	0	1.000	2	0.793
9	0.297	5	0.385	4	0.609	0	1.000	5	0.075	3	0.466	1	1.000
8	0.440	5	0.385	3	0.822	3	0.466	2	0.793	1	1.000	2	0.793

Table 2: Calculated values of P_1 for n number in the different time width of the cluster.

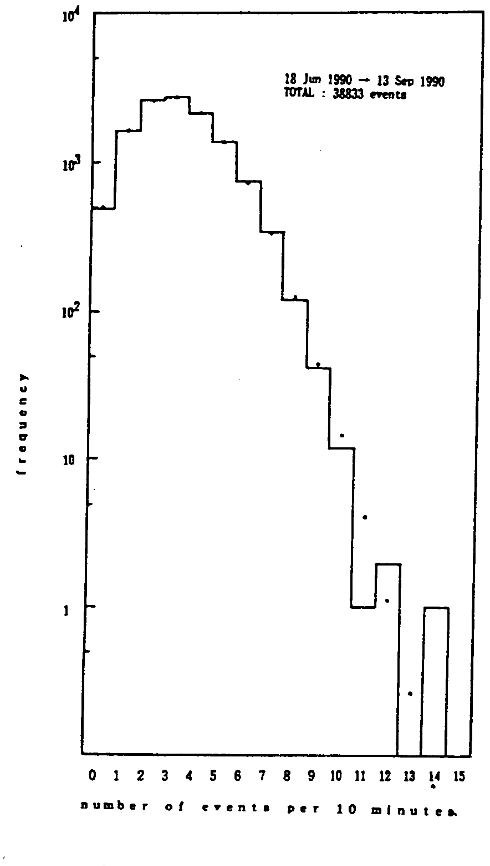

Fig. 4: The distribution for the number of events within the time scale of 10 minutes. Dots stand for expected values from poisson distribu tion.

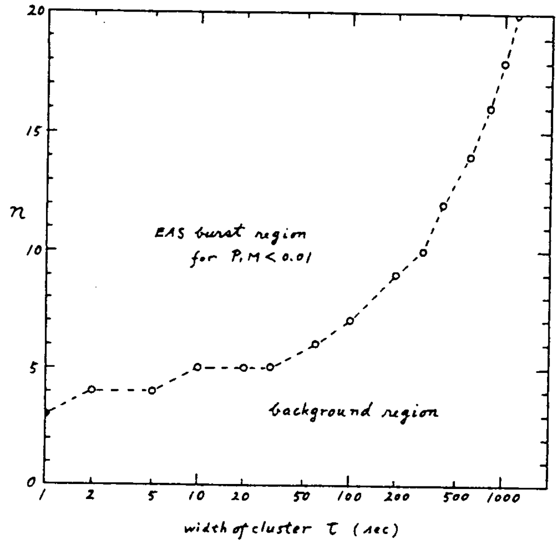

Fig. 5: A relation between the time width of the cluster and the threshold number.

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