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Search for Bursts in Air Shower Data

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1. Introduction

There have been reports in recent years of the possible observation of bursts in air shower data (e.g. Smith et al 1983, Fegan et al 1983). If such events are truly of an astrophysical nature then they represent an important new class of phenomenon since no other bursts have been observed above the MeV level. The spectra of convential gamma ray bursts are unknown at higher energies but their observed spectra at MeV energies appear generally to exhibit a steepening in the higher MeV range and are thus unlikely to extrapolate to measurable fluxes at air shower energies (see e.g. Clay et al, 1982). On the other hand, we now know that astrophysical objects are indeed capable of producing ultra high energy gamma rays and we should treat seriously the possibility of a burst acceleration mechanism.

We have looked for deviations from randomness in the arrival times of air showers above ~ 10^{14} eV with a number of systems and results so far are presented here. This work will be continued for a substantial period of time with a system capable of recording bursts with multiple events down to a spacing of 4 μs . Following the suggestion of Fegan et al (1983) that their event may be related to a glitch of the Crab pulsar, we have also searched our earlier data for the possible association of air shower events with a glitch of the Vela pulsar.

2. Detecting Systems

Four detecting systems were used in this work. Data from the earlier Buckland Park array was used to search for bursts from the direction of the Vela pulsar. This system has been described in detail elsewhere (Crouch et al [1981]). Data from the new Buckland Park array with a substantially lower energy threshold has been searched for evidence of any non-random component. This array is described in this conference (Clay et al 1985a). We have also used two simple air shower triggers employing, in each case, two scintillators in coincidence. One detector pair was operated at Adelaide with a 5.6m spacing (detector area 0.16 m^2) and a median detected shower size of $Ne = 4 \times 10^4$ particles. The second system, operated at Perth, consisted of two scintillators (area .07 m^2) with a spacing of 6m giving a median shower size of 3×10^4 particles.

3. Searches for any Non-Random Effect

We have previously searched for non-random effects in our air shower time spacing distribution by testing our spacing distributions to see whether or not the exponential form extended to small time spacings. A non-random effect associated with bursts would be likely to result in an excess of small spacings. Since we have no 'a priori' reason for expecting a particular burst time scale, we have fitted exponentials (see Fig 1) for each data set above a

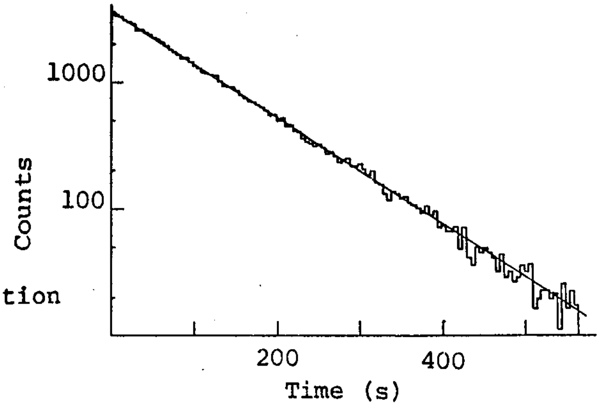

Fig 1. Pulse spacing distribution measured at Adelaide.

lower time spacing limit chosen subjectively by taking into account the recording pulse rate and then compared the number of events expected below this limit with the number actually observed. The results are shown in table 1.

Table 1

Experiment (Recording-Time)	Spacing range for fitted exponential	Mean event spacing	Number exp. below range	Number obs. below range
Buckland Park (964 hrs)	150-1000s	312.6s	4193±63	4192
Adelaide (2139 hrs)	50-1000s	103s	28732±106	28576
Perth (2488 hrs)	400-4000s	977s	3139±43	3183

One might also ask whether or nor there is any evidence for bursts in the data sets in terms of any series of small time intervals rather than an excess in the total number of small time intervals. We have examined our data and calculated for each system the number of times expected for observing a series of 3, 4 or 5 successive intervals, each below a certain minimum spacing. The results are shown in table 2.

Table 2

Experiment	Number of times consecutive time intervals are <t.					
(time-interval t)	3 intervals		4 intervals		5 intervals	
	expected	observed	exp.	obs.	exp.	obs.
Adelaide (20s)	230	221	35.9	44	6.1	8
Buckland Park (2s)	1301	1270	196	245	30	41
Perth (200s)	62.7	71	11.8	10	2.2	2

It is apparent that our data showed no evidence of any non-random effects with a total exposure of 5591 array-hours.

4. Discussion Previous experiments which have reported the observation of UHE bursts have operated for periods of the order of a year. That is, long monitoring periods are required. In order to design an experiment to search for such bursts with the greatest efficiency in terms of data processing effort and use of the available data, it is instructive to examine tables 1 and 2. Bursts of the type detected by Fegan et al. and Smith et al. would have been detected readily by the technique employed in Table 2 but probably not at all by the method used in Table 1. A useful way of searching for bursts would then be to minotor any short time intervals between air shower events and to search for any periods which exhibit a series of such short time intervals. We are now using a time interval measurement device which responds to pairs of events with time spacings below 0.5s (compared to a mean rate of one per 9s with the new Buckland Park array) and records the occurrence of such an event together with the spacing (in units of 4μs). Bursts can then be identified by the observation of a succession of such short intervals. This is statistically powerful since the probability of having many successive small intervals by chance falls rapidly with the number of intervals.

5. The Association of Bursts with a Pulsar Glitch Fegan et al 1983 suggested that their observed burst may have been associated with a pulsar glitch. The Vela pulsar is at a declination which is easily observed from Adelaide and we have searched our 1979-1981 data set (1.3×10^5 events) for all events within our angular uncertainty arriving from the direction of the Vela pulsar (see Protheroe et al., 1984). The result of this search is shown in Fig. 2. These data show no evidence for any clumping. There is one day which contained three events but such an occurence has a probability of ~66% in a data set of this kind. The Vela pulsar exhibited a glitch in this time period as indicated but no closely correlated events stand out.

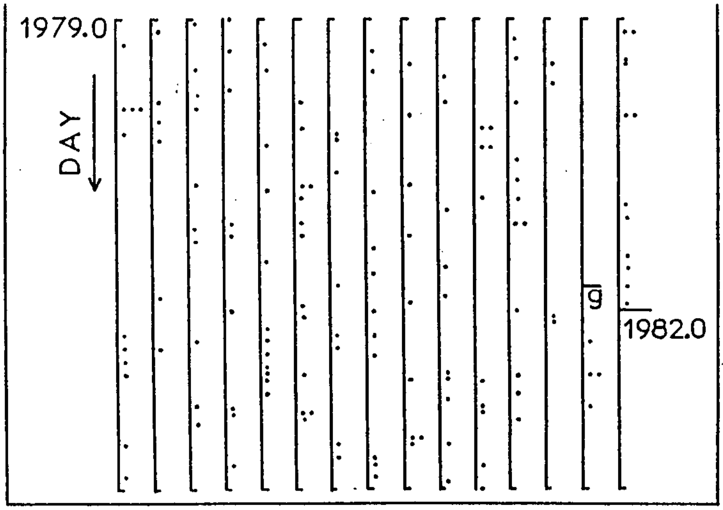

Fig. 2 The day of arrival of events from the direction of the Vela pulsar. Each column represents 75 days of data. The time of a glitch is shown as g.

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