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Search for 10–1000 km range correlations of air showers in LAAS experiment

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Correlations between EAS datasets recorded at very-distant (10–1000 km away) stations have been searched for. The stations, operated by the Large Area Air Shower (LAAS) group in Japan, are precisely synchronized by the GPS. Assuming some sporadic burst activities of UHE cosmic ray sources, we picked up coincident and parallel EAS events. From recent EAS data of six stations, we could not find any significant events.

1. Introduction

The Large Area Air Shower (LAAS) group has been operating EAS stations at eleven sites in Japan. The stations are precisely synchronized by the use of GPS. Since mutual distances between stations are 10–1000 km (except some station-combinations), normal ('solitary') EAS can not trigger multiple stations coincidently and we can not expect any correlations between EAS datasets recorded at the distant stations.

Here we assume some sporadic activities which can induce correlated EAS in the earth's atmosphere over a very large area, e.g. bursts of ultra-high-energy (UHE) cosmic ray sources accompanying UHE γ-rays, or the GZ effect[1]. We searched for such events in our EAS datasets by picking up coincident and parallel EAS pairs registered at distant stations. This report is an updated one from our earlier paper [2].

2. Experiment

The LAAS experiment consists of eleven compact EAS arrays scattered over a large part of Japan. Each station has 5–8 scintillation counters to detect EAS particles and the GPS receiver to record EAS arrival times with accuracy of 1μsec. In this report, EAS datasets recorded at six stations are employed, as listed in Table 1. Mutual distances between the stations are 10–160 km except combinations of OUS–OUS and OU–OUS. We evaluated the performance of our detectors by the CORSIKA code[3], that is, the angular accuracy of 7–10 degrees and the mean EAS energy of 600–1000 TeV [4]. In this report, EAS with the zenith angle less than 45 degrees were used. For details of the LAAS experiment, see reference [4].

Table 1. The LAAS stations and data profiles used in this analysis († EAS with $\theta \leq 45°$)

Station Name	Abbr.	N_c	Trig. Rate (/day)†	Data Period
Okayama Univ.	OU	8	1.4×10^3	05/14/2002 – 12/31/2004
Okayama Univ. of Science 1	OUS1	8	1.4×10^3	05/21/2002 – 12/31/2004
Okayama Univ. of Science 2	OUS2	8	3.0×10^3	05/29/2002 – 12/31/2004
Okayama Univ. of Science 3	OUS3	5	2.8×10^3	12/29/2002 – 12/31/2004
Kinki Univ. 1	KU1	5	4.6×10^2	05/22/2002 – 12/31/2004
Nara Univ. of Industry	NUI	7	4.0×10^2	01/02/2003 – 09/22/2004

Table 2. The coincident and parallel EAS events (time difference$<$ 300μs and angular distance$<$ 10 deg.)

ID	TD (μs)	MTD (μs)	AD (°)	Stations	Date,Time	α	δ	θ	ϕ
A	200	184	8.6	OU	10/01/2002	104	24	11	183
				↪KU1	76810.116	102	16	19	192
B	118	248	5.4	OUS1	06/08/2004	149	29	13	111
				↪KU1	24855.123	156	30	18	100
C	14	110	1.9	KU1	03/22/2004	220	31	13	100
				↪OUS2	59981.1841	224	30	15	101

3. Analyses and results

As the first step of the coincident event search, we compared arrival times and shower angles of all EAS pairs for all station-combinations (except combinations of adjacent stations: OUS–OUS and OU–OUS). Considering the distance between stations and the angular accuracy of the arrays, we picked up EAS pairs with the time difference (TD) less than 300 μs and the angular distance (AD) less than 10 degrees as 'coincident and parallel' events.

Table 2 shows the three EAS pairs picked by this analysis. In this table, MTD means the *modified time difference*. If primary particles come into the earth on an exactly-flat plane, an 'expected' TD arises due to the large distance between the stations, as is shown in Figure 1 (ΔT). MTD is obtained by subtracting TD by ΔT, which is calculated from mutual positions between the stations and the average shower angles ($\bar{\theta}$ and $\bar{\phi}$). This is the conception that we use the network system as the 'cosmic ray interferometer'. Taking into account the number of events we used, the significance level of the three events is not so high and the results are consistent with chance coincidences. However, the 'event C' should be noted because it has a very small TD and a very small AD.

We also searched coincidence events among three stations and four stations with looser TD/AD restrictions, but no significant events were found. To accumulate more coincident EAS events, we recently modified our detector system [5].

4. Conclusions

Using EAS datasets registered at distant (10–160 km) stations, we searched for coincident and parallel EAS pairs to detect correlations of primary cosmic rays over a very large area. With the restriction of time difference

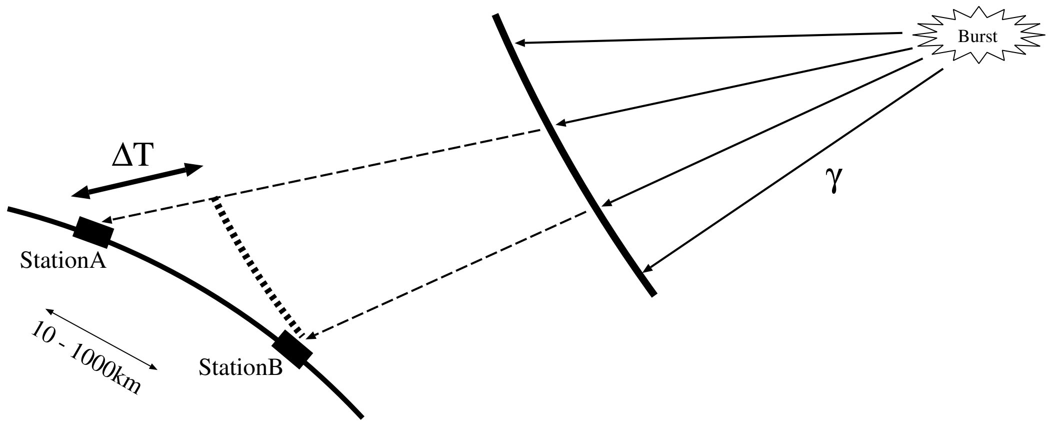

Figure 1. The conceptual sketch of the 'cosmic ray interferometer'

less than 300 μs and angular distance less than 10 degrees, we picked up three EAS pairs. However, the significance level of the events was not so high and the results are consistent with the chance coincidences.

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