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Study of the arrival time structure of serial air showers

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Abstract. The arrival time structure of serial cosmic rays is carefully examined, using air shower data from five stations of the Large Area Air Shower (LAAS) group in Japan. This study is motivated by reports of the observation of non-random structure in arrival times of serial air showers. We count the number of air showers (N) observed within short time windows and compare it with the Poisson distribution. The observed N distribution almost agrees with the Poisson as expected from the conventional view of completely random structure of serial cosmic rays. However, a small but intriguing discrepancy between them is found in the largest-N range. The formation mechanism of this anomalous feature is discussed.

1 Introduction

Historically there are several reports on the detection of non-randomness in arrival times of air showers. Smith et al. detected a 'burst' of 32 air showers of the mean energy 3 PeV within a time window of five minutes (Smith et al., 1983). Fegan et al. reported the detection of an unusual simultaneous increase of air shower rates at two stations separated by 250 km (Fegan et al., 1983). Katayose et al. applied a cluster analysis to the arrival time series of air showers and found five 'clustered' events (Katayose et al., 1998). The arrival directions of the 'clustered' events grouped about two regions on the Galactic plane.

Though the formation mechanism of these non-random cosmic rays is still an open question, it should have significant astrophysical implication. Here we report the result of searching for non-randomness in our own air shower data by a rather simple procedure (see also our previous report; Ochi et al., 2001b).

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2 Experiment

The air shower data used in this analysis have been collected by five stations of the Large Area Air Shower (LAAS) group in Japan. The experimental details of the LAAS group are described in Ochi et al.(1999). In short, each station consists of 4 to 8 scintillation counters. The mean primary energy and angular accuracy, estimated by CORSIKA, are 1 PeV and 7.0 degrees, respectively (Ochi et al., 2001a). The Global Positioning System (GPS) records arrival times of air showers with an accuracy of 1 μs. The data used in this analysis spans the period from September 1996 to April 2001; the same with that used in Ochi et al.(2001c).

3 Analysis and discussion

In order to investigate whether our air shower data contains non-random components, first we count the number of detected air showers (N) within a time window. The width of a time window is varied between 20–60 min. depending on daily trigger rates, so that the average of N's is 10. By shifting the time window through the whole data period, we get the N distribution. This procedure is done independently for each station data set. If air shower data does not contain any non-random components, the N distribution will agree with the Poisson distribution. If some deviations are found between them, it may be indicative of non-randomness in arrival times of air showers.

When we apply this procedure to all air showers in a data set, the resulting N distribution agrees with the Poisson distribution very well. This is confirmed for all station data sets.

Next, we divide the total N distribution into two distributions; one for time windows with higher daily trigger rates and the other for time windows with lower daily trigger rates. This procedure is based on the assumption that when the daily trigger rate is high the detector is more sensitive to lower energy cosmic rays, so air shower data contains more non-random components. Figure 1 shows the N distribution

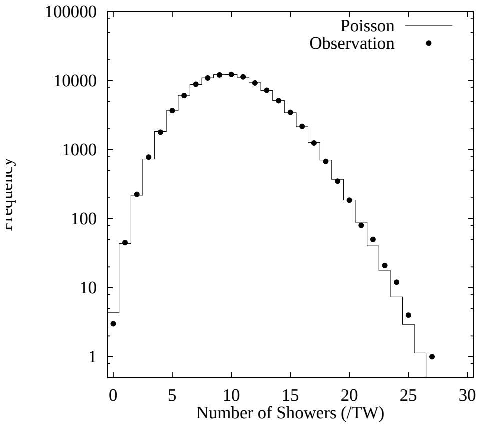

Fig. 1. The N distribution for higher trigger rates.

for time windows with higher daily trigger rates. The upward deviation of the observation from the Poisson is found in the largest-N bins, though the significance is not enough. No deviation is found for the N distribution of lower daily trigger rates. In other words, the deviation from the Poisson is observed when the local trigger rate is very high. This result is comparable with previous reports described earlier.

The arrival directions of air showers in the deviated region are also investigated. They show a tendency to group about the Galactic plane, but the significance of it is not enough either. We need to analyze more air shower data to judge whether this is due to real non-randomness in cosmic rays or due to fluctuation.

If the grouping is not by fluctuation but by a kind of emission from the Galactic plane, ultra-high-energy γ-rays are presumable for it. The superposition of a few γ-rays on conventional cosmic rays seems to be enough to explain non-random components detected here. Unfortunately, it is unknown whether the observed events contain γ-induced showers, because we do not have muon detectors.

4 Conclusion

We search for non-random components in arrival times of air showers, using five stations' data of the LAAS group in Japan. When the trigger rate is very high, the upward deviation of the N distribution from the Poisson distribution can be seen, but the significance is not enough. To confirm the existence of non-randomness and its directional preference to the Galactic plane, we need more EAS data and more sophisticated analytical procedures.

References

Fegan, D. et al., Phys. Rev. Lett., 51, 2341, 1983.
Katayose, Y. et al., Nuovo Cimento, C21, 299, 1998.
Ochi, N. et al., Proc. 26th ICRC (Salt Lake City), 2, 419, 1999.
Ochi, N. et al., Nucl. Phys. B (Proc. Suppl.), 97, 165, 2001a.
Ochi, N. et al., Nuovo Cimento, C24, 2001b.
Ochi, N. et al., 'Search for coincident air showers over a very large area', this conference, 2001c.
Smith, G. et al., Phys. Rev. Lett., 50, 2110, 1983.