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Analysis of the Arrival Time of Successive Air Showers by using *Erlang Distribution*

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Abstract: We analyze arrival time of air shower using Hirosaki AS Arrays. This array consists of 5 scintillation detectors with GPS antenna for arrival times. We use *Erlang Distribution* and *High Order Correlation Method*. The number of air showers observed within short time windows is analyzed by using arrival time difference of k-events serial air showers. We report the results of the analysis.

Introduction

We analyze arrival time of air shower using Hirosaki AS ArrayU which consists of 5 scintillation detectors and GPS(Location:$40°35'$ N, $140°28'$ E, 63m from sea level)[1]. By using the GPS, we can record arrival times of air showers with an accuracy of 1 micro second. Any 3-folds coincidence within 100 nano seconds is used on the trigger condition for air shower events. The event rate is 3600 / day. Some special successive air shower events are recorded in short term among observation data which we will be explained later. Recently, N.Ochi et al. group [2] and T.Konishi et al. [3] reported that the arrival direction of such the successive air showers tends to concentrate to the Galactic plane. Relating to their reports we analyzed similar problems by two algorithm. One is with *Erlang Distribution* and the other is with *High Order Correlation Method*. The period from October 5, 2006 to January 8, 2007 were selected for the analysis.

Analysis by using *Erlang Distribution*

Let us explain, how to utilize the Erlang distribution [4] for extracting the peculiar feature of successive air shower events. Here we sample successive air shower events, for example, six events. We take the time difference of No.1 event to No.6 event as first sample, that of No.2 to No.7 as the second, that of No.3 to No.8 as the third and so on. From these samples, we obtain frequency distributions of successive air shower events. In Fig.2, we compare observation with *Erlang Distribution* and found significant difference between observation and the expected from *Erlang Distribution*. We found significant discrepancy in smaller time difference, as shower in Fig.2.

Analysis by using *High Order Correlation Method*

It explanes *High Order Correlation Method*. To search out a series of successive air shower events, the first we set the time width and number of successive air shower events. If the difference of time in the set number of events is in the fixed time width, we calculate the arrival directions of the air shower events in equatorial coordinates(the right ascension and the declination). The first event in the events is taken out as data when everything is in the range that the events specified. One sample that began to be applied is actually shown in Fig.3 and Fig.4 by using this method.

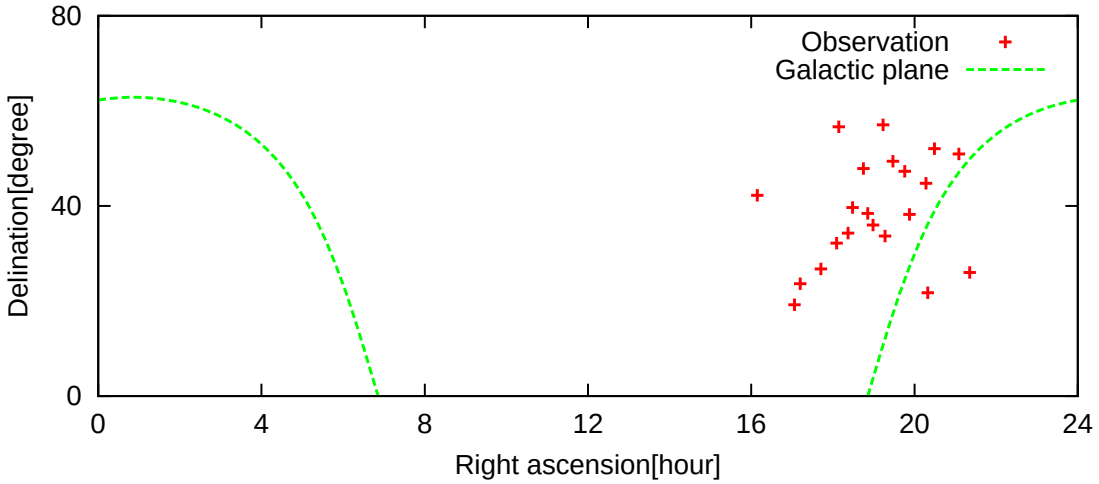

Figure 1: The events extracted by using *Erlang Distribution* are plotted in equatorial coordinates.

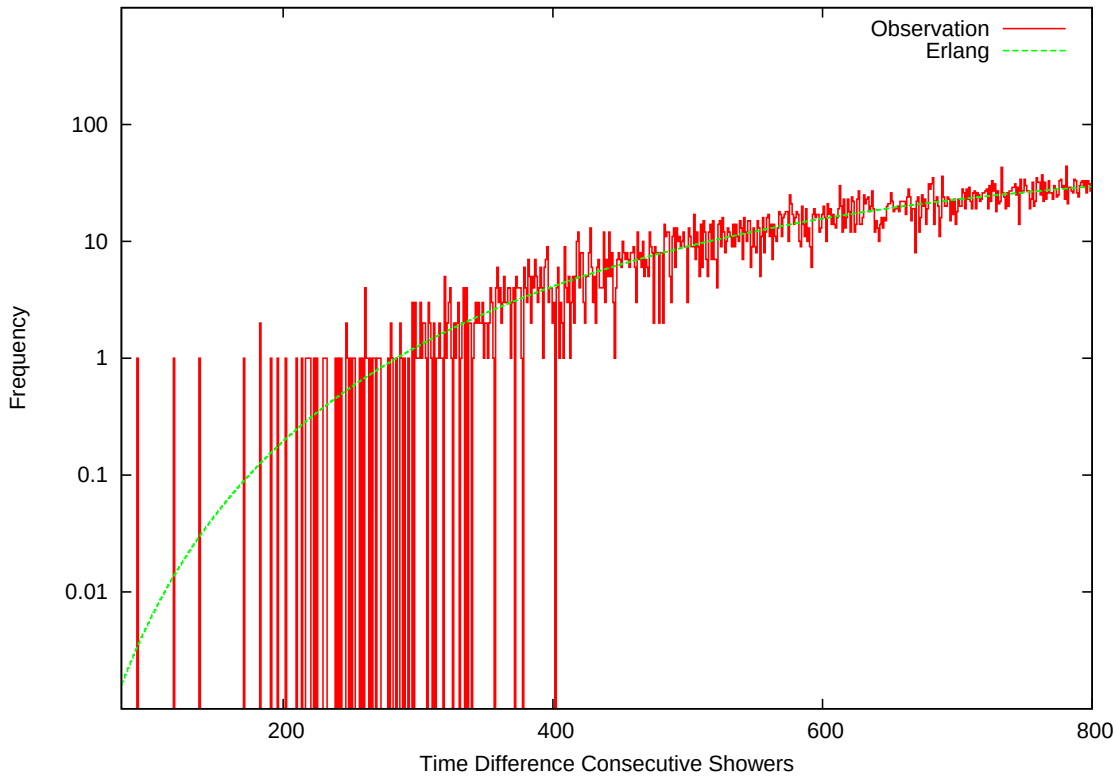

Figure 2: The frequency distribution and *Erlang Distribution*(k=7).

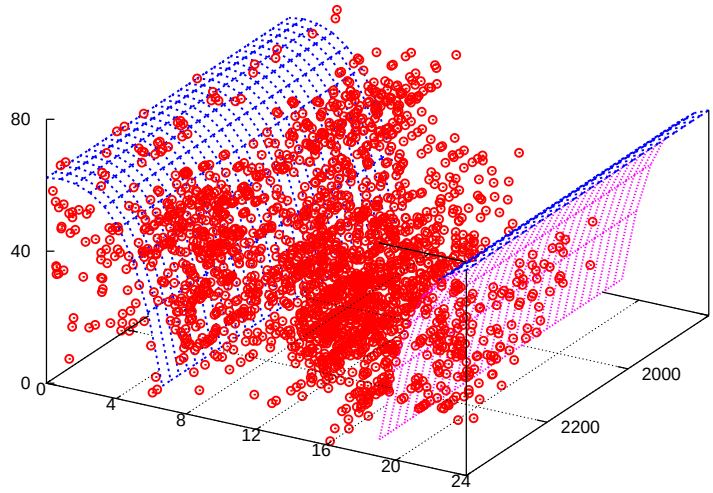

Figure 3: Before selection by using *High Order Correlation Method*. X axis is time width[sec], Y axis is right ascension[hour], and Z axis is declination[degree].

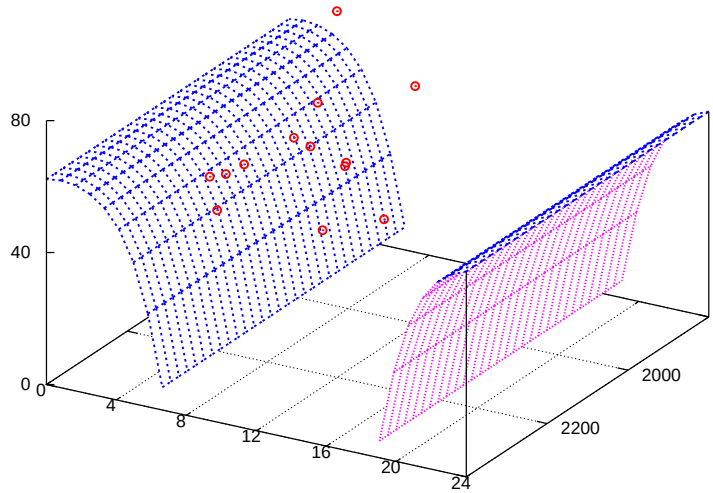

Figure 4: After selection by using *High Order Correlation Method*. X axis is time width[sec], Y axis is right ascension[hour], and Z axis is declination[degree].

Conclusion

In the analysis by using *High Order Correlation Method*, it is possible to look for the events with cluster from the arrival time of successive air showers searched out by the using *Erlang Distributon* analysis. When the density of cluster is high, it is deeply related one in direction and time width in the k events. Result of analysis, it has been understood that the cluster events with high density exists. *High Order Correlation Method* is effective in this cluster analysis.

References

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