The Periodicity of the Cosmic Ray Chaos

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Abstract

The Large Area Air Showers(LAAS) are tried to detect simultaneously by several installations of LAAS Group in Japan. The time dependence of the chaos of the air shower arrival time intervals(ASATIs) has the periodic hehaviour. The frequency and the phase of the periodicity is found to be coincident with the chaos of the ASATIs detected by the different installations at 165km distance.

1 Introduction

The time sequence of ASATIs including several hundreds events were applied to the fractal dimension analysis introduced by Grassberger et.al.[1] and the chaotic features were found in cosmic rays with average primary energy $3 \times 10^{14} eV$ [2][3][4]. The same analysis is applied to ASATIs to search the time dependence of chaos of cosmic rays. The number of each ASATIs for the analysis is less than 200 events during $12h$ or so in our observation obtaining the time resolution of the analysis. The time dependence of the chaos of the short ASATIs gives the fine time structure of the randomness of long ASATIs during a week.
The simultaneous observations of ASATIs on different installaitions at long distance are executed by LAAS group since 3 years ago. We will be able to get some informations about the large area air shower with long range correlation of the primary cosmic ray for the searching of coincidence of the chaos of the ASATIs of the different installations.

2 Analysis and Results

The ASATIs observed in three installations, Nara University of Industry, Kinki University and Okayama University are applied to the fractal dimension analysis. In this analysis, the self similarity of the topology reconstructed from the original sequence of ASATIs is estimated as the fractal dimension. The total number of ASATIs are about 200,000 events observed in three installations during from Jul. 1996 to May 1997. The trigger rate is about 300 events/24hour on Nara installation for instance. The analysis is performed for every 300 ASATIs

stepping by 20 events to find the constant fractal dimension on more than 1/5 distance of phase space as shown in figure 1 as the chaotic case of ASATIs. We find several cases of chaotic ASATIs during more than 30 hours for the three installations as shown in table 1. The underlines in the table show the coincident appearence of the chaos of ASATIs at different installations.
We find also quasi-chaotic ASATIs which has nearly constant fractal dimension around the chaotic ASATIs. Then the fractal dimension analysis is performed for each shorter length of ASATIs, i.e. 150 or 200 data, around the chaotic ASATIs mentioned above to get the resolution for the time dependence of the chaos. For this purpose, the slope of the fractal dimension curve is calculated for each ASATIs as shown in figure 2. The time dependence of the slope of the fractal dimension curve for ASATIs during a week from 12th Nov. to 19th Nov. 1997 observed at Nara University of Industry and Okayama University is shown in figure 3. Around the slope 1.0, ASATIs is chaotic and, around the slope 2.0, ASATIs is random. In this figure, we can find the periodicity of the chaos and the coincidence of the frequency and the phase of the periodicity at different installation distant with 165 km. This is a surprising result from the view of the traditional image of the air showers. The frequency is estimated to be about 23hours with the Fourier power spectrum analysis for both installation. The right assension distribution of the ASATIs which have the most clear chaotic feature on the slope of the fractal dimension curve is around 4h for both data. These results suggest that the chaotic cosmic rays forms the chaotic attractor wave which arrives perpendicular to the direction of the rotation of the earth as shown in figure 4. These attractor wave should arrives to the earth along with the specified direction. So, the observation during more than 10 hours going with the rotation of the earth obtains the information of the time intervals of the attractor wave of the chaotic cosmic rays. The wave should be sometimes long enough to be observed coincidently by different installation at 165km distance.

3 Discussion

The attractor wave formed by the chaotic cosmic rays should be observed by the installations with the rotation of the earth. The attractor structure could be reconstructued well as the vector points in the phase space which is formed from ASATIs to get the fractal dimension. The length of the attractor wave of the chaotic cosmic rays is assumed to be more than a few hours rotation distance on the surface of the earth. The depth of the attractor wave along with the direction perpendicular to the surface of the earth should be a few light hours. This is expected from the simulation in which the chaotic data without noise should amount to more than 1/3 local part of the considerably choatic data as whole ASATIs during 10 hours for instance. The analysis results mensioned above suggests that the chaotic cosmic rays forming the attractor wave should start from the specified celestial objects not so far from the solar system. The

jet from the binary star SS433 has been observed to be intermittent [5]. The jet material could arrive to the earth as the cosmic rays from the specified right ascension after several thousands times Lamor rotations. The intermittent appearance of the jet could be a cause of the attractor wave of cosmic rays.

References

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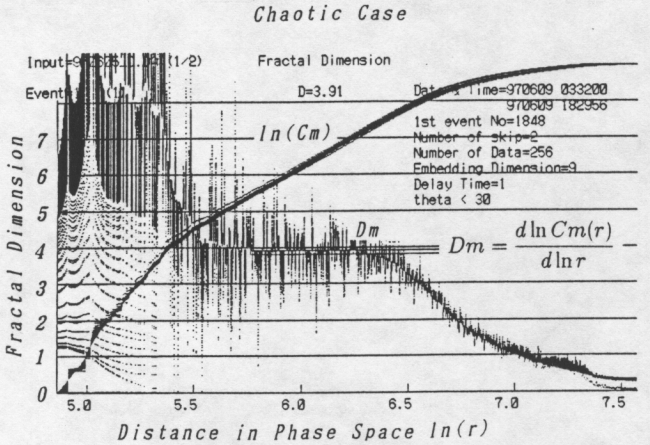

Figure 1.
The diagram of the fractal dimension analysis for the chaotic ASATIs.

	Osaka	Nara	Okayama
1996			
	25-26th Jul.	25-27th Jul.	
		29-31th Jul.	
	13-14th Nov.		
			18-20th Nov.
	3-6th Dec.		2-4th Dec.
1997			
			27-29th Apr.
		17-20th Jul.	
		25-26th Sep.	
	8-9th Oct.		
	10-12th Nov.	12-15th Nov.	12-15th Nov.
	26-29th Nov.	23-26th Nov.	
	9-11th Dec.		(9th Dec.)
1998			
	11-12th Apr.		
		3-5th may	

Table 1.
The coincidence of chaotic cosmic rays (underlined) found on Kinki Univ.,Nara Univ.of Ind. and Okayama Univ.

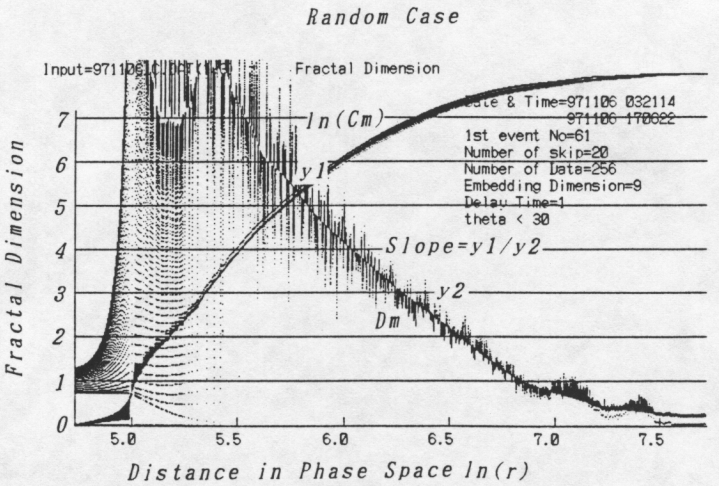

Figure 2.
The diagram of the fractal dimension analysis for the random ASATIs.

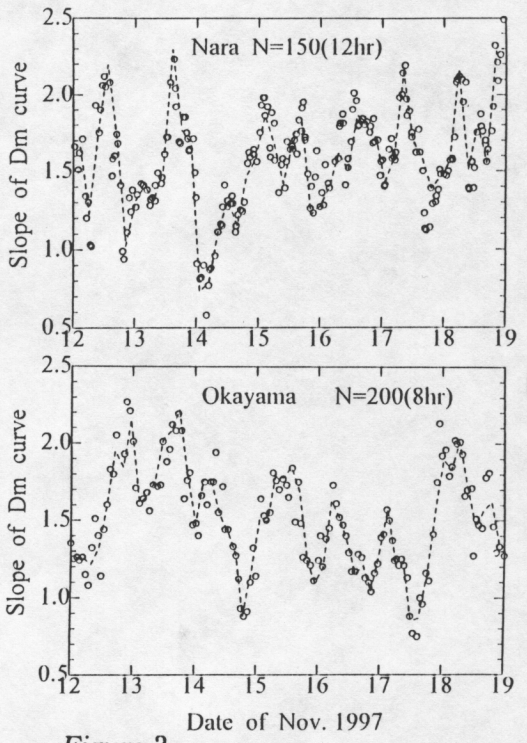

Figure 3.
The time dependence of the slope of the fractal dimension curve obtained from the ASATIs observed at Nara Univ.of Ind. and Okayama Univ. around on 15*th Nov.*1997.

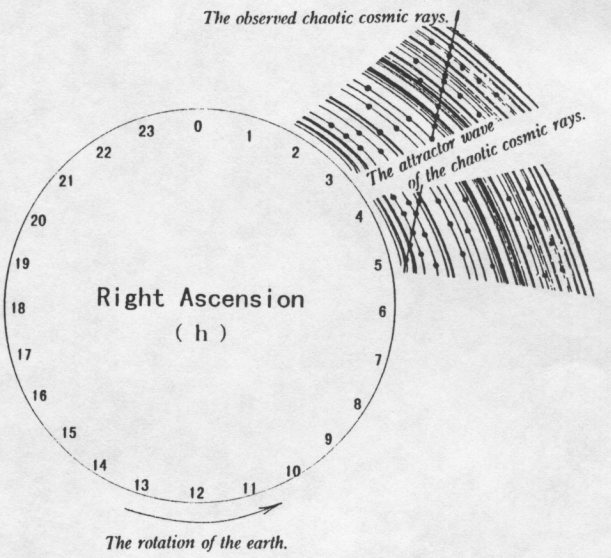

Figure 4.
The illustlation of the anisotropic arrival of the attractor wave of the chaotic cosmic rays.