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SPECTRAL ANALYSIS OF THE FORBUSH DECREASE OF JULY 13, 1982

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ABSTRACT

The maximum entropy method has been applied in the spectral analysis of high-energy cosmic-ray intensity during the large Forbush event of July 13, 1982. An oscillation with period of about 2 hours and amplitude of 1 - 3 % was found to be present during the decrease phase. This oscillation can be related to a similar periodicity in the magnetospheric field. However, the variation was not observed at all neutron monitor stations.

In the beginning of the recovery phase, the intensity oscillated with a period of about 10 hours and amplitude of $\lesssim 3$ %.

1. INTRODUCTION

One of the largest Forbush decreases (FDs) was observed on July 13, 1982. It was caused by a solar flare of type 3B on July 12 at 0916 UT at position 11 N, 37 E. The arrival of the shock front was indicated by a sudden commencement (SSC) at 1618 UT on July 13. The magnetic disturbance generated the largest geomagnetic storm ever observed in Finland. At Nurmijärvi Geomagnetic Observatory (60.5 N, 24.7 E), the horizontal component of the geomagnetic field reduced 20 % within a few hours, and returned to its predecrease level in 12 hours.

The decrease of high-energy cosmic rays began at about 1620 UT on July 13, and the recovery phase lasted several days. The amplitude of the decrease was of the order of 20 % as measured by the Turku double neutron monitor and other high-latitude monitors.

In order to find out possible periodicities in the cosmic-ray intensity during this FD, we applied the Maximum Entropy Method (MEM), proposed by Burg in 1967, in analyzing data from nine neutron monitor stations. The advantage of MEM is that it leads to much better resolution than the conventional Blackman-Tukey method. It also gives more realistic power spectral estimates, especially for short data records.

2. DATA AND METHOD OF ANALYSIS

The neutron monitor data used in our analysis are displayed in Figure 1. Before the frequency analysis, long-term trends (period > 12 hours) were removed by using the moving average method.

The power spectral density, P(f), was estimated from the equation

$$P(f) = \Delta t\, P_{M+1} \left| 1 + \sum_{k=1}^{M} \alpha_{Mk} \exp(-2\pi i f k \Delta t) \right|^{-2},$$

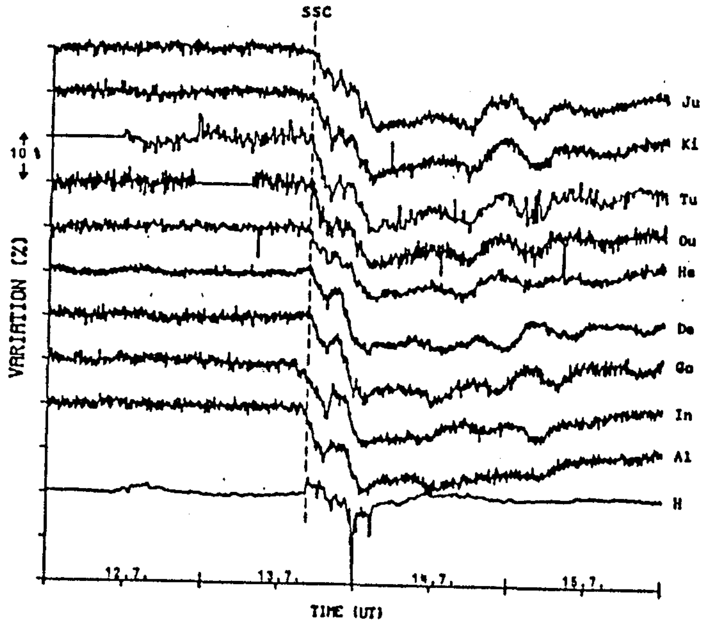

Fig. 1. Neutron monitor counting rates on July 12-15, 1982, at nime stations (see table 1 for the abbreviations). The lowest curve shows the horizontal component of the geomagnetic field as measured at Nurmijärvi station in Finland.

where f is the frequency, Δt is the time interval between the data points, and M is the length of the prediction error filter. The constant P_{M+1} and the coefficients α_{Mk} were determined from the matrix equation

$$\begin{pmatrix} \phi_o & \phi_1 & \cdots & \phi_n \\ \phi_1 & \phi_o & \cdots & \phi_{n-1} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \phi_n & \phi_{n-1} & \cdot\cdot & \phi_o \end{pmatrix} \begin{pmatrix} 1 \\ \alpha_{M1} \\ \cdot \\ \cdot \\ \alpha_{MM} \end{pmatrix} = \begin{pmatrix} P_{M+1} \\ 0 \\ \cdot \\ \cdot \\ 0 \end{pmatrix}$$

where ϕ_l ($l=0,\ldots,n$) is the autocorrelation with time lag $n\Delta t$ (for details of the method, see e.g. Ulrych and Bishop 1975). The time interval Δt was 5 or 15 min, and M was determined in the standard way ($M \leq N/3$, N = number of data points).

3. RESULTS AND DISCUSSION

3.1. Decrease phase. The decrease phase started at about 1620 UT. However, at Inuvik the onset time was about 1430 UT. The explanation is that the asymptotic directions of Inuvik rotate with the Earth so that at 1430 UT Inuvik receives particles from the direction of the interplanetary magnetic field-line. But these particles were strongly scattered by the arriving shock front, and thus their intensity decreased earlier.

The only significant variation in the frequency range $3\cdot10^{-5}$- 10^{-3} Hz occurred with periods between 112 and 126 min (Table 1). The amplitude was largest at the mountain station Jungfraujoch (≈ 3 %, as reported also by Debrunner et al. 1983). At Finnish stations (Turku and Oulu), the amplitude was $\lesssim 2$ %. An analysis of the neutron-multiplicity data of the

Table 1. The most significant periods in the cosmic-ray intensity at various neutron monitor stations.

Station		R_c^{vert} (GV)	Period (min) Decrease phase	Period (min) Recovery phase
Jungfraujoch	(Ju)	4.5	118	716
Kiel	(Ki)	2.3	115	706
Turku	(Tu)	1.1	115	706
Oulu	(Ou)	0.8	112	788
Hermanus	(He)	4.6	-	430
Deep River	(De)	1.1	-	640
Goose Bay	(Go)	0.6	-	596
Inuvik	(In)	0.2	126	540
Alert	(Al)	0.0	(119)	702

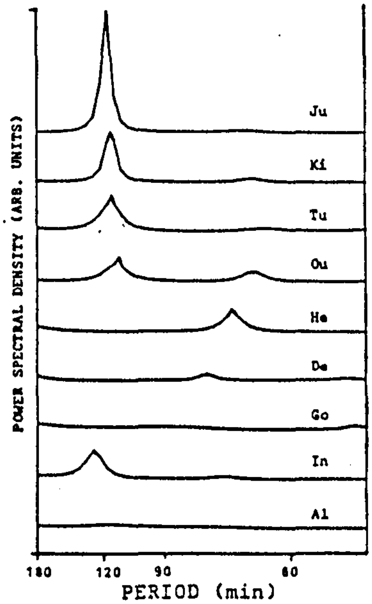

Fig. 2. Power spectral densities of the cosmic-ray intensity observed at various stations during the decrease phase.

Turku neutron monitor showed that this variation was no more present at multiplicities $\gtrsim 4$ corresponding to median primary rigidities $\lesssim 35$ GV.

The power spectral densities are shown in Figure 2. It is noteworthy that the 2-hour periodicity was practically absent at Hermanus Deep River, and Goose Bay. Further, the period 119 min of Alert is not statistically significant.

In Figure 3, the power spectral density is presented in more details around the 2-hour peak. The superiority of MEM to the conventional Blackman-Tukey method is evident.

The origin of these oscillations is clearly in the strong variation of the magnetospheric field as can be seen in Figure 4, where the observations of the satellite GOES-2 are reproduced.

3.2. Recovery phase. In the beginning of the recovery phase, rather strong oscillations were observed at all stations. The only remarkable variations occurred with a period of about 10 hours and amplitude of 3 % (Table 1 and Figure 5). A similar periodicity was found by Chirkov et al. (1983) as they analyzed data from several stations. This periodicity could be explained by the activity of the Sun. Another possibility could be successive reflections of galactic cosmic rays on

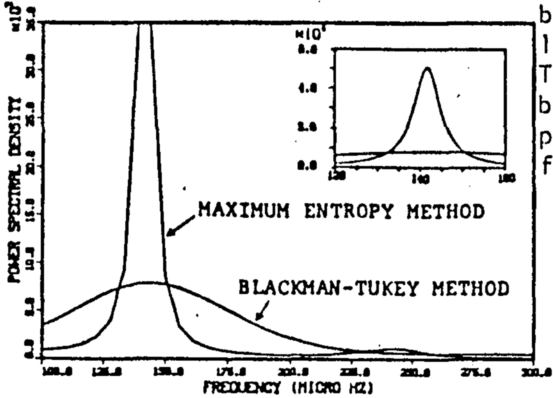

Fig. 3. Power spectral density of the cosmic-ray intensity observed at Jungfraujoch during the decrease phase. The small figure shows the density around the 2-hour peak.

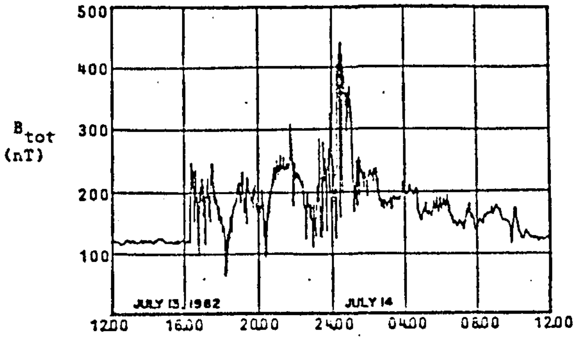

Fig. 4. The total magnetic field as measured by the satellite GOES-2 (from Parsignault et al. 1983).

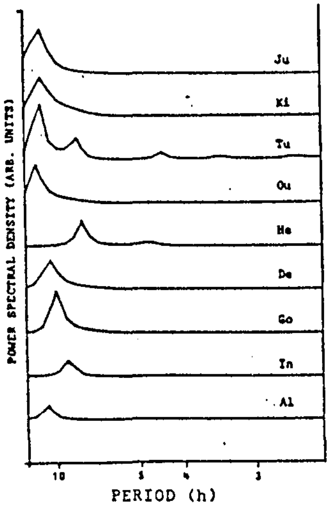

Fig. 5. Power spectral densities during the recovery phase.

the shock front.

Inspection of Figure 1 reveals some phase shifts of a few hours in the 10-hour variation (e.g. Deep River and Goose Bay vs. European stations). This feature is understood in terms of differences in the asymptotic directions of the stations.

4. CONCLUSIONS

The unusual periodicity of 2 hours during the decrease phase of the FD of July 13, 1982, is a direct consequence of strong oscillations in the magnetospheric field. The mechanism of the interactions between the solar wind and the Earth's magnetosphere leading to these oscillations requires further studies.

5. ACKNOWLEDGEMENTS

We are grateful to the following persons for providing us the neutron monitor data: G. Sebor (Jungfraujoch), K. Röhrs (Kiel), H. Kananen (Oulu), P. Stoker (Hermanus), and M. Bercovitch (Deep River, Goose Bay, Inuvik, and Alert). We also thank C. Suchsdorff for the magnetometer data of Nurmijärvi Geophysical Observatory.

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