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The Effect of Forbush's Decrease on the Solar Diurnal Variations of Cosmic Rays

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Abstract—**The intensity drop of solar diurnal variations of cosmic rays during different types of Forbush's decreases had been studied as a function of the geomagnetic cutoff rigidity. Fifty-five events of Forbush's decreases had been classified into four groups according to their shape. We had used in this study the data of six neutron monitor stations. We found that the recovery rate of neutron intensity after the action of Forbush's decreases depend on the profile of the event. It is also found that the spectrum responsible for the Forbush's decreases have a power law depending on the shape of the event.**

Keywords: Forbush's decreases,solar diurnal variations, geomagnetic cutoff rigidity, neutron monitor

I. Introduction

During the periods of maximum solar activity and the periods of solar flares in particular, when there is an increase in the magnetic field which have the ability to change the direction of the charged particles, cosmic rays that are low in energy are affected and its intensity decreases in a phenomenon known as the Forbush's decrease (which can be abbreviated to Fd).The amounts of maximum depression for the nucleonic components are as great as a few percent to ~20% from a view point of the solar diurnal variation during Fd's. This is particularly during the main phase of a sharp decrease of the intensity. So, apparent large diurnal variations are produced by the curvature effect; that is, large intensity decreases in a short period may behave like a diurnal term with the amplitude as great as >1%. This effect is considerably greater for the nucleonic components due to its low energy response (10 ~ 30 GeV).

Earlier it was suggested that these events are produced by perturbation in interplanetary condition and that these perturbation originate from solar flares or from magnetic field structures associated with interplanetary solar wind streams [1]-[3]. The perturbation would be produced from shock waves, coronal mass ejections; flare generated high solar wind streams [4]-[8]. Belov and Ivanov & Belov et al.[9]-[11] had concluded that the Fd's are also correlated with solar wind velocity.

It is a great interest to re-study the effect of Forbush's decrease on the solar diurnal variations of cosmic rays. In the previous study, we found that the effect of Forbush Decrease on the solar diurnal variations of the neutron component in both amplitude and phase is very remarkable. The solar diurnal amplitudes have larger values for stations having lower geomagnetic cut-off rigidity. The ratio between the solar diurnal amplitudes before and after the event was changing according to the profile of the event. There is a shift in the phase towards earlier hours during the period of Forbush decreases. The value of that shift also depends on the profile of the event.

In this paper, we will examine the intensity drop of solar diurnal variations of cosmic rays during different types of Forbush's decreases as a function of the geomagnetic cutoff rigidity. Fifty-five events of Forbush's decreases had been classified into four groups according to their shape. We had used in this study the data of six neutron monitor stations.

II. Method of Analysis & Experimental Data

55 events of Fd's during about four solar cycles starting from 1966 up to 2006 had been subdivided into four types according to the case of decreasing-, and recovering-phase. These four types are the type of sharp-decrease and sharp-recovery (8 events), the type of sharp-decrease and slow-recovery (38 events), the type of slow-decrease and sharp-recovery (4 events), and finally the type of slow-decrease and slow-recovery (5 events).

The Fd's which had been analyzed were taken from the list compiled by Can et al. [12] during about three solar cycles starting from 1966 up to 1994, and we had determined the Fd's events for

the other years from 1995 up to 2006 by using the same criterion of Can et al. [12].

Fourier analysis was performed for the hourly data of cosmic rays observed at Deep River, Kiel, Climax, Hermanus, Tokyo, and Huancayo neutron monitors stations after smoothing them using the technique of deviation from 24-hour running averages to calculate the daily solar diurnal amplitudes and phases. This data covers about four solar cycles from 1966 up to 2006, and corrected for the atmospheric pressure compiled by WDC-C2.

Superposed epoch analysis had been used to calculate the vectorial average of the observed diurnal vectors for every day of these types of Fd's. We had considered in our analysis three days before the starting day of Fd's, and four days after Fd's.

III. RESULTS AND DISCUSSION

The amount of cosmic ray intensity drop during the main phase of a decrease depends on the latitude of the recording station [13]. This drop of intensity has its maximum value at the pole and the lowest value at the equator.

Fig. 1 represents the structure of a typical Forbush's decrease. The recovery period may be approximated to the form:

$$\Delta I = \Delta I_0 \, e^{-t/t_0} = \Delta I_0 \, e^{-\lambda t} \quad (1)$$

where $\lambda = 1/t_0$ is the recovery constant which is the mean of the rate of recovery after a cosmic ray decrease and its value differs from case to another. ΔI is the intensity deviation from the reference level I_0 that is the mean intensity during a quiet period chosen close before the decrease. Such period must not contain irregularities as increases or decreases. ΔI_0 is the deviation at the midpoint (T_0) of a quiet internal (between T_1 and T_2) during the recovery. T_s is the time of minimum intensity.

The values of the recovery rates λ were found, as shown in Table 1, to have values ranging from 0.004 up to 0.011, on the average, depending on the shape of the event. This recovery rate for the sharp-sharp group is around three times greater than that for the slow-slow group. Also, the recovery rate had been found to be independent of the geomagnetic cut-off rigidity. This result had been found to support the magnetic tongue model proposed by (Usoskin et.al.) [15].

The fractional decrease $\Delta D/D$ of the primary intensity can be represented by:

$$\Delta D/D = a \, R^{-b} \quad (2)$$

where R is the primary rigidity and a, b are constants which may differ from storm to another [14].

Figs. (2, 3, 4, and 5) represent the rigidity dependence of the mean intensity drop for the four FD groups, while Table 2 represents the values of the constants (a) & (b). It is shown from these figures & table that the spectrum responsible for the FD is found to have a power law with exponent varying from 0.554 to 0.251 depending on the shape of the event.

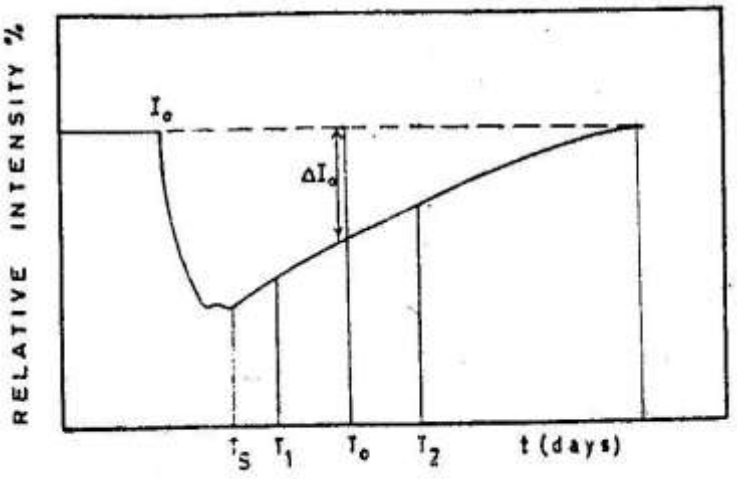

Fig. 1

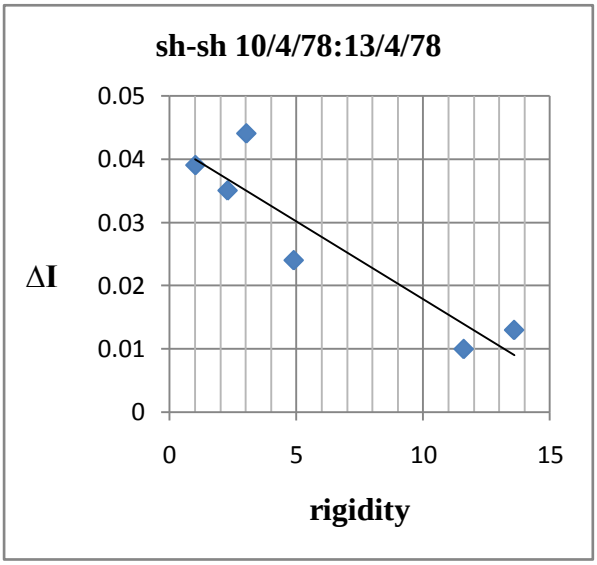

Fig. 2

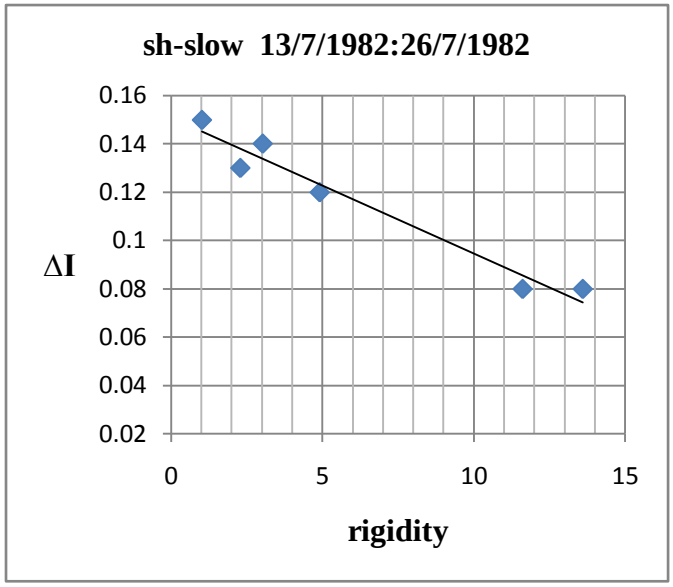

Fig. 3

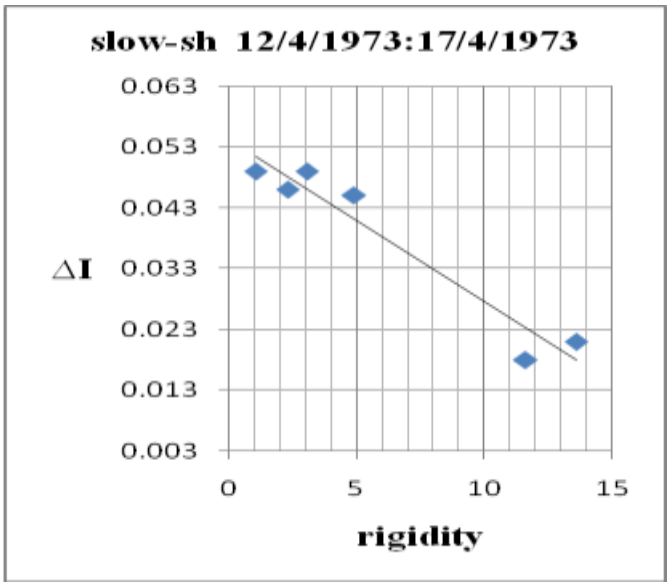

Fig. 4

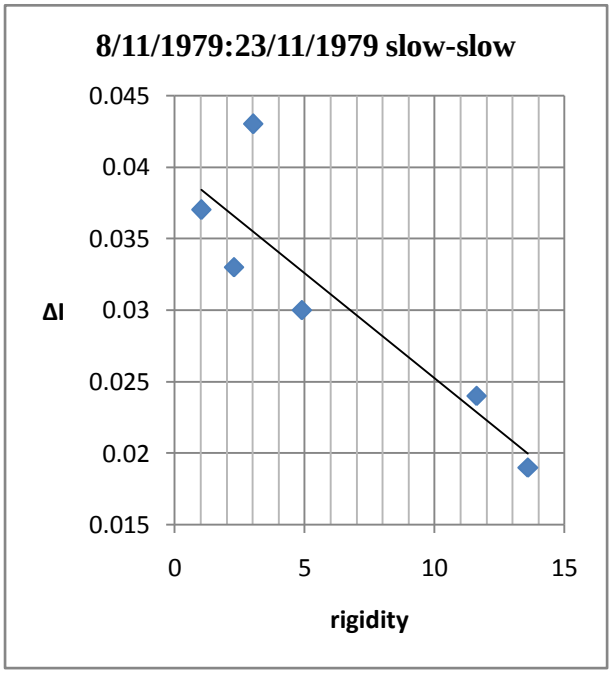

Fig. 5

Table 1: The values of λ for different types of Forbush's decreases.

Station	Rigidity of the station	sharp-sharp	sharp-slow	slow-sharp	slow-slow
Deep River	1.02	0.00873	0.00526	0.00645	0.00308
Kiel	2.29	0.00966	0.00538	0.00649	0.00303
Climax	3.03	0.00889	0.00472	0.00678	0.00386
Hermanous	4.9	0.0111	0.00551	0.0066	0.00392
Tokyo	11.61	0.01379	0.00571	0.00649	0.00488
Hauncayo	13.6	0.01198	0.0056	0.00669	0.00434
Average		0.011	0.0055	0.007	0.004

Table 2: The values of the constants a and b.

	sharp-sharp	sharp-slow	slow-sharp	slow-slow
a	0.05302	0.16563	0.06279	0.04294
b	0. 554	0.265	0.404	0.251

IV. CONCLUSION

We had studied the effect of geomagnetic cut - off rigidity on the profile of the Forbush's decreases for the nucleonic component of cosmic rays on hourly basis and during more than four solar cycles from 1966 up to 2006. It is concluded that:

(1) the recovery rate of neutron intensity after the action of Forbush's decreases depend on the profile of the event.

(2) the spectrum responsible for the Forbush's decreases have a power law depending on the shape of the event.

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