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A relation between cosmic rays and Dst field

M Lal[1] and Pankaj K Srivastava[2]
[1]Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism
Krishnapuram BO, Maharajanagar PO
Tirunelveli-627011, India
e-mail : MLAL@iig.iigm.res.in
[2]Department of Physics, Govt New Science College, Rewa (M.P)-486 001, India
e-mail : Pankaj-in-2000@usa.net.

Cosmic rays control of Dst field both on long and short-term basis is studied. It is shown that the cosmic rays is inversely related to Dst field and that there is a dominant local time dependence of the relationship. Strongest correlation are confined to the local after noon hours. It is also shown that cosmic rays as well as Dst field is influenced by the solar rotation and its harmonics. Both the parameters shows strong power spectral density of about 27 days. The Dst field on short-term basis is influenced by variable cosmic rays with a delay of about 1-2 days. It may be possible that cosmic rays power spectral density has already been enhanced by some interplanetary conditions causing the changes in Dst field on the earth before cosmic rays reach us.

1 Introduction

Besides the clear periodic and quasi periodic variations of cosmic ray (CR) intensity recorded by neutron monitor (NM), like the 11-year and the diurnal variation, the superposition of small amplitude variations, the fluctuations, lead to the observed broad-band power spectra of CR. Dhanju and Sarabhai[1, 2] first showed the cosmic ray power spectrum and discussed some enhancements in the spectral density above ~ 1.7×10^{-3} Hz in relation to the geomagnetic field changes due to interplanetary magnetic field fluctuations.

Owens and Jokipi[3,4] described the general characteristics of CR fluctuations and their relation to magnetospheric and interplanetary phenomena in a series of papers. The CR scintillations at neutron monitor (NM) energies are not explained by magnetospheric processes, in difference to lower energy particles, and may be of interplanetary origin[3]. The equation relating the CR scintillations to interplanetary magnetic field (IMF) fluctuations and to CR gradients was obtained by Owens[5]. Thus the CR scintillations may provide useful information about interplanetary fields. Theoretically, Owens and Jokipii[3,4], and Topygin and Vasilijev[6] discussed the power spectra in relation to the random magnetic field in the interplanetary space or in the magnetosheth. However, the validity of their models are limited to the frequency range less than ~10^{-5} Hz for 10GV of cosmic rays.

To decide whether CR is a geoeffective parameter even on a shorter time scale, it is essential to identify a period where the CR variation is persistent for several solar rotations not vitiated by solar transients. One such interval where the daily average solar wind speed showed very systematic oscillations has recently been provided by Gallaher and D' Angelo[7]. In this paper, we study the long term and short-term relationship of CR with Dst index using the hourly one-year data from January 1994 to December 1994. The advantage of utilizing low latitude fields in such studies arises from the fact that it can be directly related to the equatorial ring current effect whereas index Ap will be representative of both auroral substorms and equatorial ring current effects.

2 Short Term Relationship

Mean hourly values of CR variation for the period of January 1994 to December 1994 were used from the data given by Moscow neutron monitor station, Russia (A. Belov, Private Communication). We utilized the mean hourly values of Dst field as a representation of low latitude magnetic field variation during this period in the increasing phase of solar cycle.

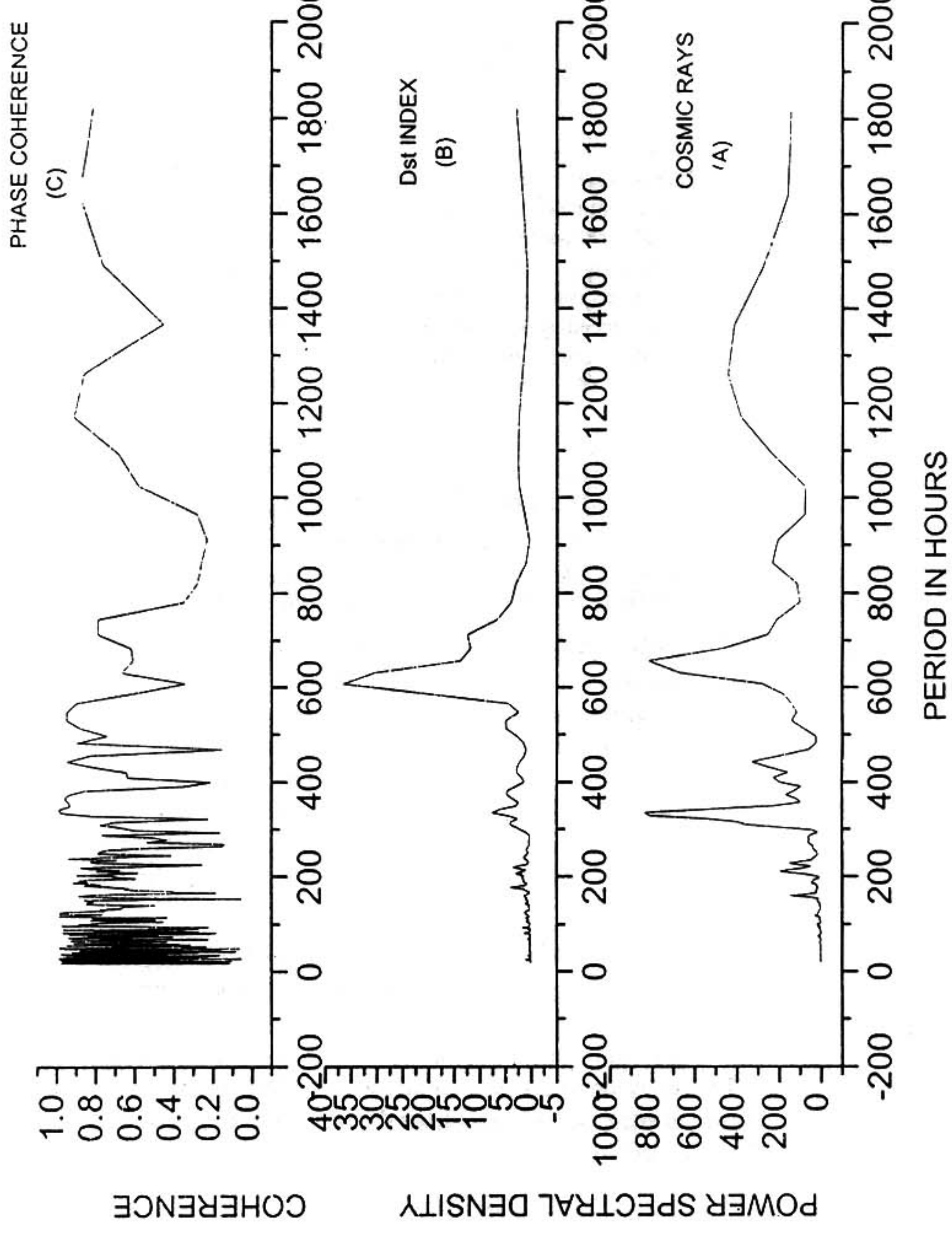

Fig 1. Power spectra of mean daily cosmic rays

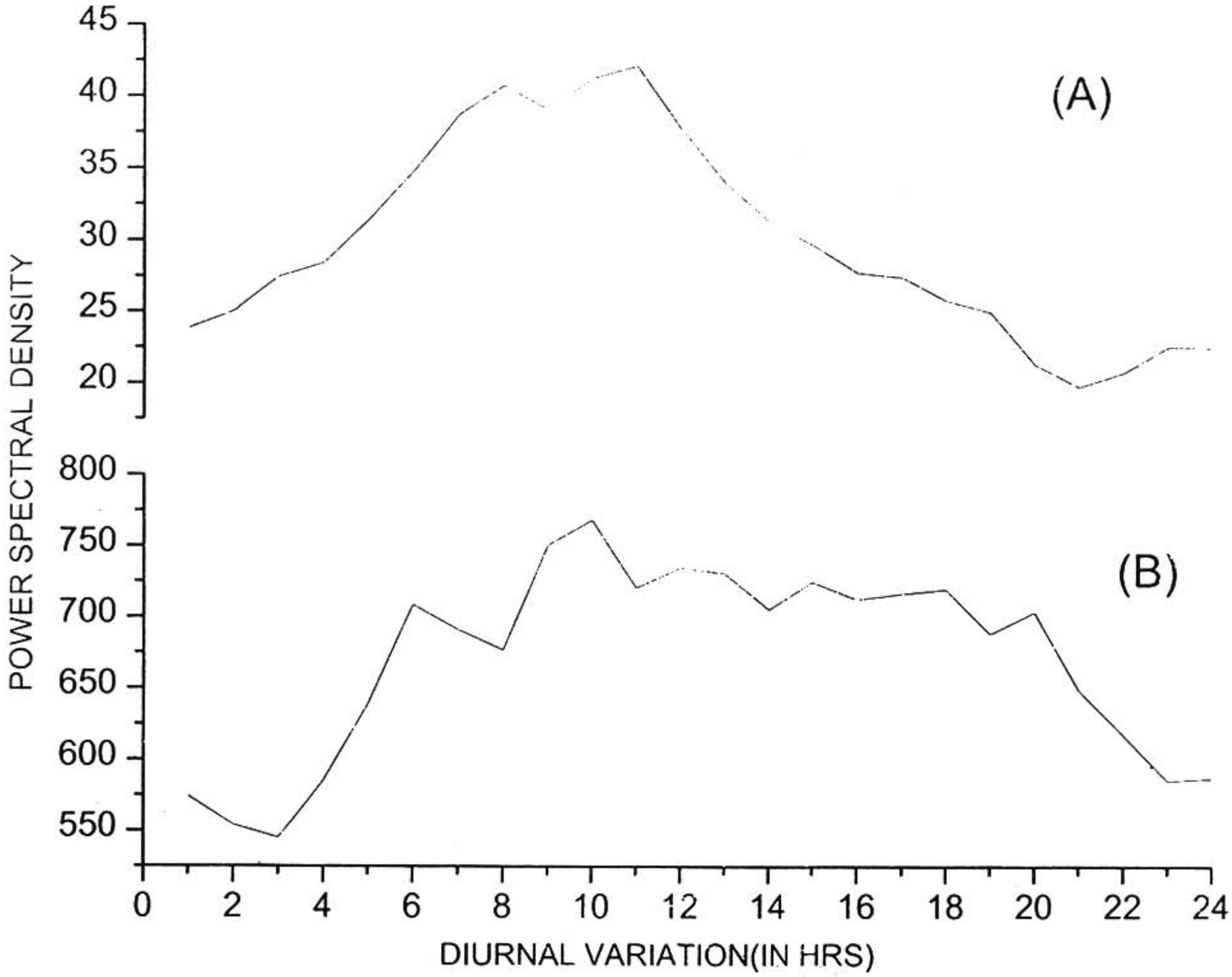

Fig 2 Power spectral density variation of cosmic rays.

3 Results and discussion

Power spectra of mean daily cosmic rays restricted to hourly averages at a time, clearly indicated the presence of dominant periodicity near 27 days and its harmonics (52 days and 14 days). Similarly Dst field power spectral density shows the presence of dominant periodicity near 26 days and its harmonics (46 days and 13 days). Fig. 1 c shows the phase coherence between these two time series.

In Fig 2 we show the power density of the 27-day spectral peak as a function of GMT. Fig. 2a shows the power spectral density variation of cosmic rays. Fig 2b shows the power spectral density variation of Dst field. This figure clearly shows the asymmetry with noon period. Bhargava[8] and Rangarajan[9] have reported the forenoon/evening asymmetry in the strength of earth's magnetic field. This figure shows that both the parameters (CR and Dst field) are weakest in signal of about 0100 GMT and largest at 1000 GMT. Cross spectra were computed between the cosmic rays and Dst field variations for different hours. All the spectra indicates high coherence at frequencies corresponding to the harmonics of solar rotation period. But the power spectral density of solar rotation period is very much significant for all the parameters considered in the present study. While the spectral peaks near 27 days is almost coincident in frequency, that for the two harmonics for the cosmic rays appears shifted relative to that for Dst field variation.

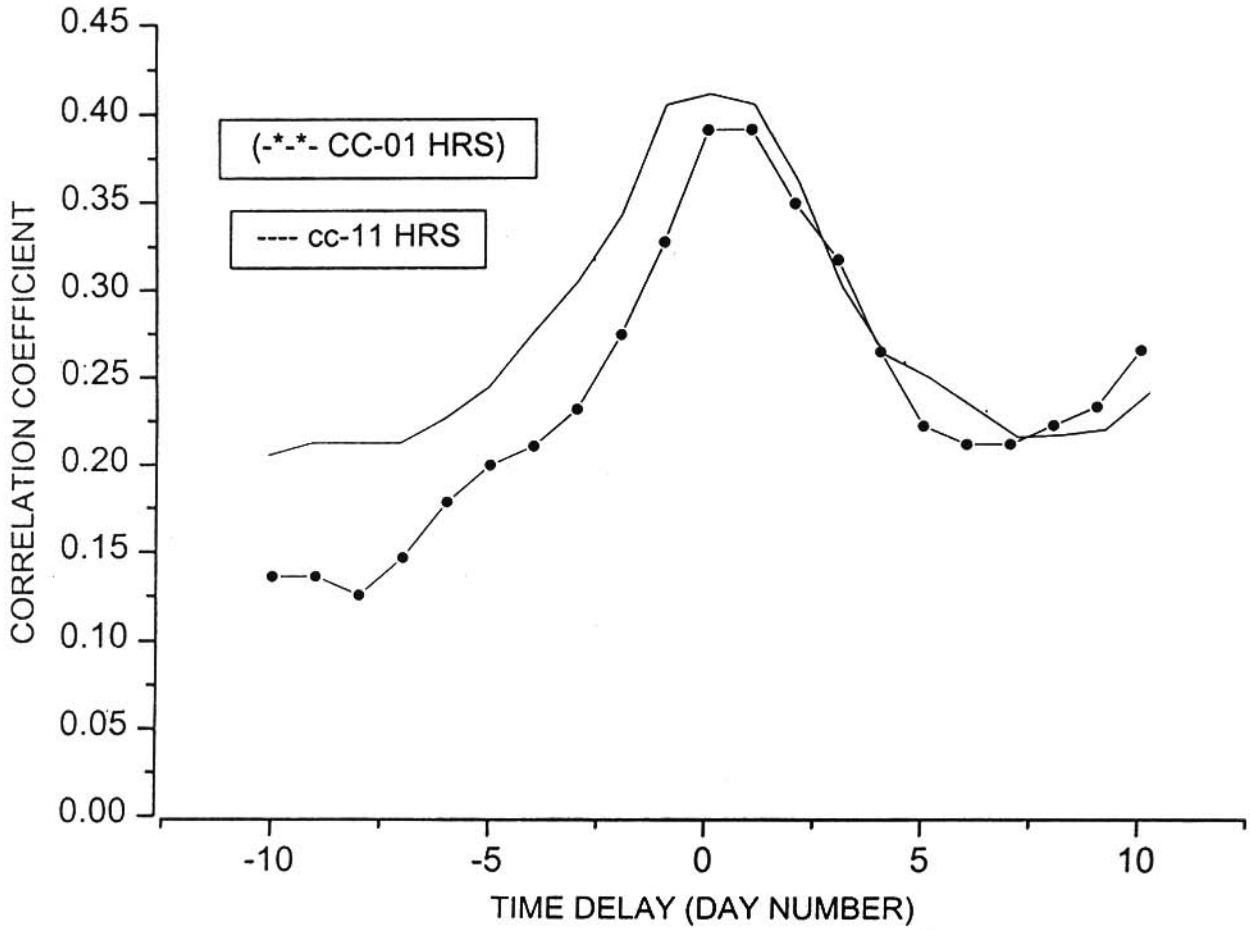

Fig 3 The change in CC with time lag.

To clearly establish the cosmic rays dependence of the low latitude Dst field and to estimate the time lag between the causative mechanism and the effect, we computed lagged CC between the mean daily cosmic rays and Dst field centeres on 10 hrs and 01 hrs GMT (corresponding to maximum and minimum power density for the 27-day signal). The correlation's were calculated for different time lags between – 10 and +10 days. The change in CC with lag is shown in Fig 3. For 377 pair of points, CC in excess of 0.22 is significant at 95% confidence level. It is clearly seen from the figure that irrespective of strength of the recurrence activity of the Dst field the plots of correlations vary quite similarly with largest negative values. It can, therefore, be inferred that the Dst field is an important parameter in causing cosmic rays depressions even on a short-term basis. This result is consistent with the similar results obtained by Kudela *et al*[10].

Apart from the time lag, we have also tried to find the correlation between cosmic rays and Dst field. Fig. 4 shows the correlative variation between CR and Dst field. The linear regression curve is in the form of $Y = AX + B$, where $A = 3.6$, $B = 8.9$. The correlation coefficients between these show CC = 0.3998.

We have estimated the power spectral density for different hours of the year 1994. The peak power spectral density of 27 days period has been calculated for cosmic rays as well as Dst field. Earlier, Sakai[11] has shown that there exists the correlation between the power spectral density of cosmic rays and Dst. The power spectral density of cosmic rays and Dst field variation is shown in Fig. 5. This figure shows the logarithmic correlation between the power spectral density of cosmic rays (=X) and that of Dst field (=Y). The regression curve is expressed by the expression $Y = A + B.X$, where $A = -11.14563$, $B = 0.06128$. The CCs between these parameters

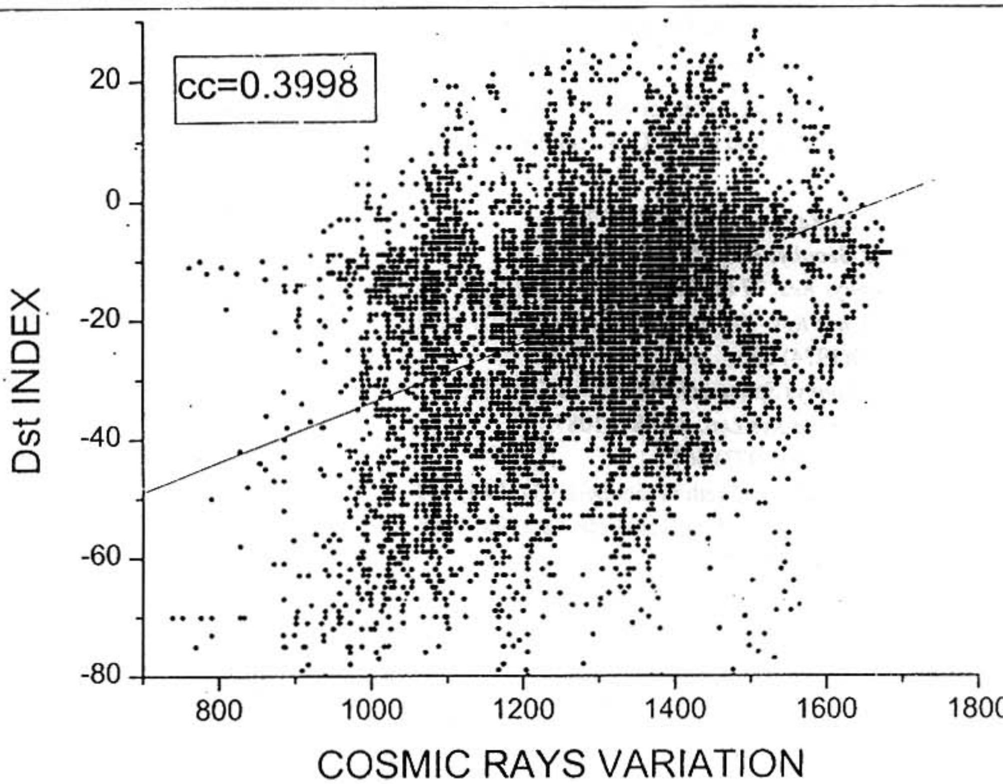

Fig 4. Correlative variation between CR and Dst field

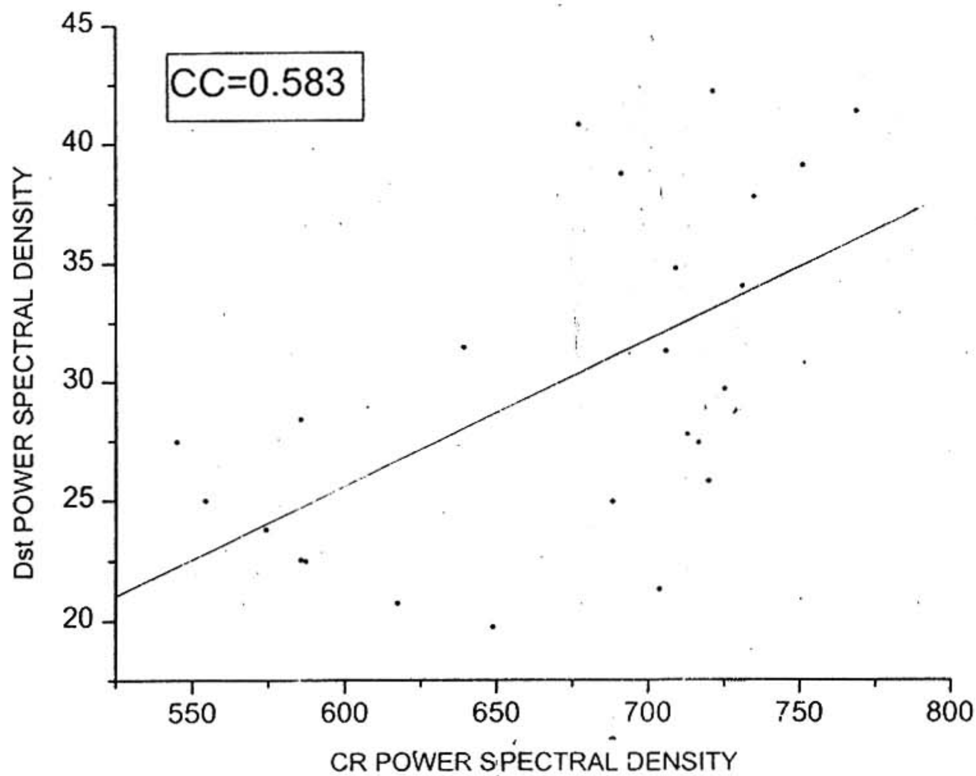

Fig 5. Power spectral density of cosmic rays and Dst field variation

is found to be 0.58245 with standard deviation by 5.89%.

The variations of CR are not affected only by "local" interplanetary state (IMF and solar wind measured near the earth orbit), but they reflect the distribution of IMF inhomogeneties within the heliosphere. Redistribution of IMF inhomogeneties, induced from the sun, can be thus sensed by CR earlier than, interplanetary travelling shock reach the earth and consequently a geomagnetic disturbance occurs.

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