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The average behaviour of the daily variation of cosmic ray intensity has been studied for a long period of time. On the monthly average basis, there are periods when the diurnal amplitude is significantly low and when the time of maximum differs very much from its average values. The monthly average amplitude is found to decrease almost to zero during Feb.-Mar. 1977, and the diurnal phase was observed in the morning hours. The anisotropy characteristics during this period are determined and compared with those of earlier periods of low amplitudes such as the period July-Sep. of the years 1976 and 1954. It is shown that the small diurnal amplitude during Feb.-Mar. 1977 is not due to low values on individual days, but due to wandering of phase around the clock throughout the period. The individual days show either normal diurnal amplitude or, on many days, even higher than normal values. These results are shown to be important to confirm the type of recurrence pattern in the diurnal variations once in 22 yr.

1. Introduction

The average behaviour of the daily variation of cosmic ray intensity has been studied for a long time using the data of both the neutron as well as meson monitors. The detailed analysis using the neutron monitor data are now available for more than two decades. Even complete phase reversal of the diurnal vector was noticed during July-Sep. 1954, which has been now attributed to unidirectional interplanetary magnetic field. However, such an observation has not been reported since then, even though the unidirectional field was observed for some time during the months of March and April of 1965 (Ref. 3). The monthly average amplitude remained within a factor of two or less as compared to their long term average value, while the diurnal time of maximum remained absolutely the same.

Based on the systematic study of the daily variation on monthly average by using the daily variation plots for the last 10-15 yr, periods of very low diurnal amplitudes have been noticed at neutron monitor energies, which occurred consecutively for 2-3 months. One of these, viz. July-Sep. 1976, has been briefly discussed by Agrawal et al. and Kaul et al. These workers have claimed that the negligible diurnal amplitude observed during this period is associated with the unidirectional interplanetary magnetic field (IMF). We have noticed an event occurring during Feb.-Mar. 1977, which is shown to be distinctly different as compared to that of July-Sep. 1976. The characteristics of this Feb.-Mar. 1977 event is derived and discussed.

2. Observational Results

The hourly pressure-corrected cosmic ray intensity recorded by neutron monitors has been used to determine the Fourier components of the daily variation for each day. The long term changes in the data have been removed by the method of moving averages. The mean monthly variations are then obtained by vector addition of the daily values which are also used to determine the standard error of the average vector.

The daily variation of cosmic ray intensity recorded by neutron monitors has been reported earlier to be almost constant till the year 1970, whereas the time of maximum of diurnal variation has advanced to earlier hours since then. Such a conclusion is valid both for short and for long periods of time. The diurnal anisotropy is generally consistent with the corotational anisotropy, with the diurnal amplitude $\approx 0.3$ to $0.4\%$ as observed by the high latitude neutron monitors. A detailed and systematic search of the data using monthly mean values of the diurnal amplitude and phase has revealed that during July-Sep. 1976 (Ref. 6) and Feb.-Mar. 1977, the amplitude of the diurnal variation has decreased to a value $\lesssim 0.1\%$. The small
amplitudes observed during July-Sep. 1976 have special significance, as they occur after 22 yr of the previous low values observed first in the year 1954. It may be noted that the daily mean value of the cosmic ray intensity is almost constant during both of these events. This automatically avoids any ambiguity in the results due to universal time related changes such as Forbush decreases or solar flare effects (see Figs. 2 and 3). Since the basic characteristics of July-Sept. 76 event has already been reported,6,7 we present in this paper the salient features of only the Feb.-Mar. 77 event.


The monthly mean diurnal amplitude has decreased once again very significantly during the two months February and March of 1977 just after the solar activity has started recovering from its minimum values in July 1976. It is noticed that the decrease in amplitude is more pronounced in high latitude stations as compared to that at low latitude stations. The mean monthly diurnal amplitude for periods including this event is depicted in Fig 1. Fig. 1 shows that the average diurnal amplitude is almost zero, while the time of maximum is in the morning hours. It also shows that there is no significant change in amplitude and phase of the semi-diurnal variation during these two months. To understand the behaviour of the diurnal anisotropy during these two months, we have plotted the frequency histograms for diurnal amplitude and phase for these two months along with that for two months earlier and later. These three groups, which are shown in Fig. 2 do not reveal any significant differences among them as far as the distribution of diurnal amplitude is concerned. However, there is a marked difference in the distribution of diurnal phase for the period Feb.-Mar. 1977. It is apparent that the phase distribution is almost
4. Discussion

Agrawal et al. \textsuperscript{6} have shown in a preliminary investigation that during the period of July-Sep. 1976, the diurnal amplitude has decreased very significantly compared to their long-term average values. Furthermore, it was shown that the decrease in amplitude during these months is associated with the “away” polarity of the interplanetary magnetic field. Similar structure in the interplanetary magnetic field has been observed during July-Sep. 1954. However, the diurnal amplitude at that time was almost zero and the time of maximum was in early morning hours. Such an indication of early morning maximum has been noted by Kaul et al. \textsuperscript{1} for July-Sep. 76, for Gulmarg station with cut-off rigidity \(\gtrsim 11\) GV, which requires further confirmation by other equatorial monitors. It appears, therefore, that the low amplitude diurnal wave has a dominant recurrence tendency as observed in 1954 and 1976. However, the similarity between them on individual day basis is not yet established. The distribution of the time of maximum is particularly important, because the low values of diurnal amplitude can either be produced by an actual decrease in amplitude on individual days, or by the random or systematic wandering of the phase all around the clock. In fact, the event described here represents the second situation.

In this context, the event of Feb.-Mar. 1977 reported for the first time, is very interesting. In this case the amplitude distribution is almost similar to what one would expect on long-term average basis. The diurnal phase during these two months is randomly distributed around the clock in complete contrast to that observed during other periods (Fig. 2). This has resulted in decreasing the average monthly amplitude to negligible values. During this period the direction of interplanetary magnetic field is observed to be changing fast within a day or two and the sector pattern is almost absent, and
hence these days can be classified under the category of mixed polarity days. Therefore, the 4-5 days pattern in diurnal phase is presently not understood since the conditions in the interplanetary medium are expected to have been steady for about 4-5 days. Nevertheless, detailed interplanetary parameters would be necessary to find its association with the anomalous pattern reported in this paper for Feb.-Mar. 1977.

Thus a completely different set of event of very low diurnal amplitude has been recognized during the recent solar activity minimum, where on individual days the diurnal amplitude is either normal or even high. Since the distribution of phase on individual days has not been reported during the months of low diurnal amplitude in the year 1954, it is not possible to associate the 22-yr recurrence pattern with this or the earlier event of July-Sep. 1976. Nevertheless, the similarity of single sectorial pattern during July-Sep. 1954 and 1976 (Ref. 6) suggests that the diurnal amplitude might have been observed to be small on individual days during July-Sep. 1954. Nonetheless, the result presented herein are very much suggestive of the need for caution in interpretation of long term averages of daily variation, particularly when the average amplitudes are small.

5. Conclusions
(i) There are continuous periods of 2-3 months in July-Sep. 1976 and Feb.-Mar. 1977, when the diurnal amplitude of the cosmic ray intensity is almost negligible.
(ii) During the period Feb.-Mar. 77, the individual days are associated with normal diurnal amplitude or even many times higher than normal values.
(iii) The diurnal time of maximum is distributed all over 24 hr and hence the larger amplitude on individual days, when averaged with almost opposite phase, yields negligible monthly average amplitudes.
(iv) The similarities between the values of July, August and September of 1954 and 1976 show a recurrence pattern of 22-yr in the diurnal variation. However, due to non-availability of daily diurnal vectors of 1954, it has not been possible to compare the behaviour of diurnal amplitude on a day-to-day basis. It is probable that the pattern of 1954 is similar to that of Feb.-Mar. 1977.

With the availability of more data from high as well as low latitude neutron monitoring stations, it will be possible, in future, to derive the detailed characteristics of the daily variation during these periods and to determine if the characteristics are significantly different from their long term average values. Moreover, with the availability of interplanetary data, it will also be possible to identify the sources of the anomalous variations reported here.

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