COSMIC RAY DENSITY GRADIENT AND ITS DEPENDENCE ON THE NORTH-SOUTH ASYMMETRY IN SOLAR ACTIVITY

Badruddin, R.S.Yadav and N.R.Yadav
Space Science Group, Dept. of Phys., A.M.U., Aligarh (India).

ABSTRACT

An analysis of the diurnal anisotropy on geomanetically quiet days has been performed using neutron monitor data at Deep River($R_c \sim 1.02$GV), Leeds($R_c \sim 2.20$GV), Rome($R_c \sim 6.32$GV) and Tokyo ($R_c \sim 11.61$GV), well distributed in latitude and longitude for the period 1964-79. The days have been separated according to the polarity of IMF on that day. A significant difference in the amplitude and phase has been found on towards and away polarity days particularly during the years of high solar activity and large north-south asymmetry. These results (particularly time of maximum) on geomanetically quiet days show some better relationship to the expected results as compared to the results obtained using all the days in a year.

I. Introduction. The existence of perpendicular gradient has been studied by separating the cosmic ray diurnal vectors into groups corresponding to the direction of IMF. This method has been recently applied (Kananen et al. 1981; Swinson and Kananen, 1982) by using the neutron and meson monitor data for the period 1965-75. These authors have found that the amplitude of the diurnal anisotropy on away polarity days exceeds those of towards polarity days during year 1965-68 and that the reverse is generally the case after the reversal of sun's polar magnetic field in 1969-71. These data points to a cosmic ray gradient, perpendicular to the ecliptic plane, pointing southward prior to 1969 and there was some evidence about northward pointing gradient after the reversal of sun's polar magnetic field in 1969-71 except in 1974. However, the phase does not show the effect expected from the amplitude behaviour. They found no significant difference, in the amplitude and phase both, of the away and towards polarity days in 1969-71, at neutron monitor energies.

We found in our paper that on day-to-day basis the coherence for the cosmic ray anisotropy is better for days of low to average solar wind speed, which also is related to geomagnetically quiet days, and it would be more meaningful to use only these days for determining the annual average of the cosmic ray daily variation particularly for sunspot maximum activity period, during which one observed large number of cases of time varying isotropic changes in cosmic ray intensity. In this paper we have analysed the neutron monitor data for 1964-79 period for the stations mentioned above on magnetically most quiet days and determined the amplitude and phase for away and towards polarity days separately. On the basis of these results the perpendicular density gradient are discussed. Some indirect information about the three dimensional structure of the heliosphere especially current sheet has been inferred from these results.

2.Result. Fig.I shows that the amplitude on away polarity days is ,in general, higher than on towards polarity days during I964-68.But the phase on towards polarity days is higher than the away polarity days during this period.The difference in amplitude and phase on away & towards polarity days are more pronounced during the higher solar activity period I967 and I968.These results are in agreement with the results of the earlier workers(Hashimand Bercovitch,I972; Kananen et al.,I98I;Swinson &Kananen,I982).However the results of Kananen et al.(I98I) for the time of maximum does not show the right type of effect as expected.We found using the data from three neutron monitors, for geomanetically quiet days that the results for the time of maximum are also generally in agreement to that expected from the amplitude behaviour during I964-68,especially in I967 and I968.To give a better representation,we have plotted the average vectors for the period I964-68,separately on away and towards polarity days (Fig.2).

Kananen et al.(I98I) and Swinson & Kananen(I982) do not found any significant difference in the amplitude and phase on away and towards polarity days during I969-7I.Their results imply no density gradient (pointing northward or southward)during this period of reversal of sun's polar magnetic field.The solar activity was high and north-south asymmetry was also quite large(and positve)throughout the period I966-70(Badruddin et al.,I983).We see from Fig.I that the amplitude at Deep River and Leeds,which was higher for away polarity days than for towards polarity days during the year I964-68,changed to higher value for towards polarity days than away polarity days in I969 though at Rome similar change has been observed in I970.However,as far as phase is concerned,it has changed to later hours for towards polarity days than the away polarity days in I969 at all the three stations Deep River,Leeds,& Rome.In I970,the amplitude was much higher for towards polarity days than away polarity days and the time of maximum was quite significantly changed towards later hours for away polarity days than towards polarity days.These results are also shown on the vector diagram in Fig.2.In many earlier studies it has been assumed that the IMF in northern and southern hemispheres have reverse configurations in I964-68 and I969-79.The north-south asymmetry in solar activity in I969-70 was of the same sign(positive) as it was in I967-68.Thus if the current sheet was displaced downward due to positive north-south asymmetry in I967-68,it will be the same case in I969-70.But since the IMF polarity may be different in northern and southern hemispheres in I967-68 and I969-70,the reverse behaviour of diurnal amplitude and phase on away and towards polarity days in I967-68 and I969-70 may be due this reason. However,in I97I,when solar activity was lower as compared to I969 and I970 and north-south asymmetry was also small in this year,no significant difference in amplitude and time of maximum for towards and away polarity days is observed at

all the four stations(only the amplitude at Deep River shows some diffrence).Similar difference at Deep River was also reported by Swinson and Kananen (I982).

During the period I971, I972 and I973 there is some difference in the amplitude at towards and away polarity days only at Deep River.The average vectors for the period I97I-I973 have also been shown in Fig.2 for all the four stations.During these periods there was no marked north-south asymmetry as evidenced form solar flares.Swinson and Kananen (I982)did not found a consistent northward gradient at meson monitor energies during I97I-73, though their results point to a northward gradient in I972 and in I973 for Deep River and Oulu neutron monitors.

In I974 the amplitude on away polarity days is higher than the towards polarity days.Various arguments have been advanced to explain the observed amplitude and phase behaviour in I974(Swinson &Kananen,I982;Ahluwalia & Riker,I98I).It is to be mentioned here that the north-south asymmetry in solar activity was some-what negative as evidenced from solar flares and moreover in I973-75 the monster type solar wind straams were prominently observed.

In the solar activity minimum period I975-76, there is no appreciable difference in the amplitude and phase values for towards and away polarity days.The north-south asymmetry was also very small during these years.However, in I977,there is some evidence for a northward pointing gradient as seen from amplitude at Deep River and the amplitude and phase at Tokyo for towards and away polarity days.The solar activity in I977 was not high and north-south asymmetry was also small.However there was an accelerated increase in solar activity after mid-I977.

In I978 & I979 the solar activity was very high.However, the north-south asymmetry was small.We see from results for amplitude and phase on away and towards polarity days that there is no appreciable difference in amplitude and phase for the two types of days both at Deep River and Tokyo.

3.Conclusion. From the above results we see that there is an appreciable difference in the amplitude and/or phase on towards and away plarity days during years of high solar activity and large north-south asymmetry.During the years of lower solar activity and/or small north-south asymmetry this difference is not appreciable.These results support the view that at least during the period of high solar activity and appreciable north-south asymmetry,either the density gradient pointing away from the solar equatorial plane is not symmetric or the current sheet might have been displaced from the ecliptic plane.Thus it seems right to suggest(Swinson,I983) that in order to detect any $\vec{B} \times \vec{\nabla} N$ anisotropy the position of the current sheet(on average)would have to be displaced from the ecliptic plane due to asymmetric activity on the sun.

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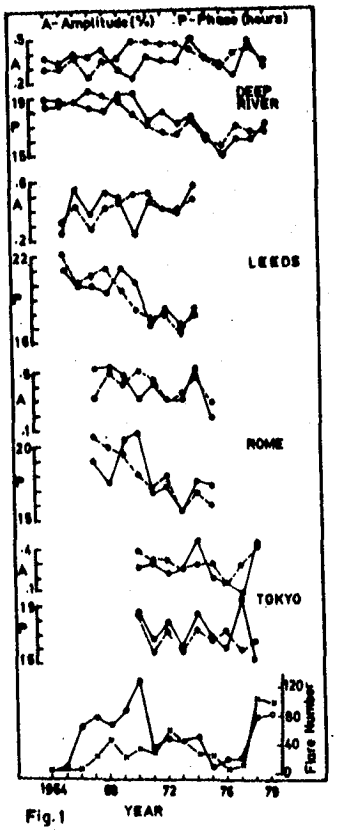

Fig.1

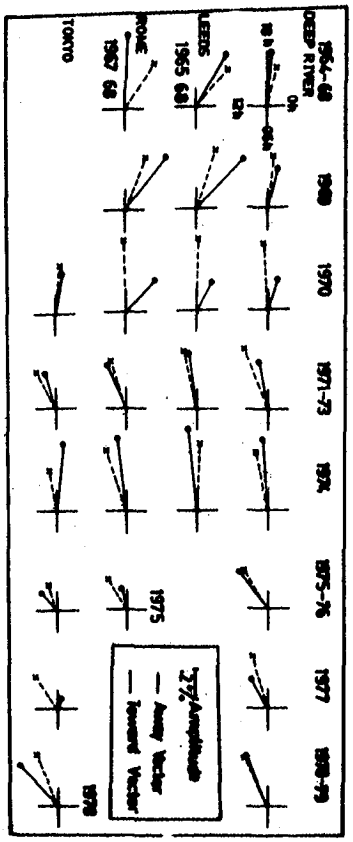

Fig.2

Fig.I shows average amplitude(A) and phase(P) of away polarity days(solid line) and towards polarity days(broken line)from I964-79.The diagram in the bottom shows the major solar flares numbers in respective years in northern(circle) and southern(crosses) hemispheres.
Fig.2 shows the average diurnal vectors on away polarity days(solid line)and towards polarity days(broken line) for the years and stations indicated.