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Influence of magnetic field of solar plasma on galactic cosmic rays

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Abstract : Two types of interplanetary disturbances namely, magnetic clouds events (MCE's) and bi-directional events (BDE's) are taken to study the short-term changes in solar wind plasma components as well as in cosmic ray intensity. These two types of disturbances are again separated into two categories : (i) coronal hole associated events (MCE's and BDE's), and (ii) without coronal hole associated events (MCE's and BDE's). Coronal hole associated BDE's are found significantly responsible for enhanced plasma velocity. Both disturbances in either the category, produce short-term decrease in cosmic ray intensity.

Keywords . Interplanetary disturbances, cosmic rays, solar wind parameters.

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Interplanetary disturbances with a shock wave at 1 AU are classified into two categories : first in which the shock wave is accompanied by a magnetic cloud known as magnetic cloud event (MCE), the second type of event where the shock wave is followed by a plasma region with bi-directional solar wind electron heat flux (BEHF) is termed as bi-directional event (BDE). It has been found that the plasma and magnetic field characteristics of these two types of transient disturbances are distinguished markedly. If magnetic cloud and BEHF are truly fast magnetized plasmoids moving away from the Sun into interplanetary space, then the interplanetary magnetic field must be draping around them [1]. This field line draping around BEHF is treated as a likely source of the out-of-the ecliptic magnetic fields at 1 AU [2,3]. IMF draping was thought of as being the possible cause of the characteristic eastward deflection of BEHF at the Earth's orbit. This provides insight into the physical nature of these two interplanctary transients.

In this paper, a systematic study has been performed to draw the relationship of magnetic field characteristics of MCE and BDE with various interplanetary/geomagnetic phenomena as well as with cosmic ray intensity. MCE and BDE events data with an accuracy of 1 hour from the period 1978–1982 are taken from IMP 8 and ISEE 3 observations [4]. The shock wave in the solar wind is generally identified in high time resolution plots of solar wind plasma and magnetic field data as abrupt and simultaneous increases in bulk flow speed V, particle density N_p, proton temperature T_p and magnetic field B [5]. Solar wind components values are taken from interplanetary medium data book [6]. For cosmic rays, we have taken the daily mean temperature and pressure corrected values recorded by super neutron monitor at Calgary (lat. 51.05° N, long. 114.08° W, cut-off rigidity 1.09 GV). We have applied super posed epoch analysis to find short-term effects.

It is established that magnetic clouds events (MCE's) and bi-directional events (BDE's) consist of different plasma and magnetic field characteristics. Such disturbances in interplanetary medium certainly produce influences on energetic particles of galactic cosmic rays as well as the disturbances in Earth's magnetic field. Coronal holes are the regions on the outer surface of the Sun, propagating high-speed solar wind stream into interplanetary medium. We have divided both MCE and BDE into two classes : one that is associated with coronal holes and another, which are not associated with coronal holes and then explicitly analyzing their influences.

Figure 1 shows the results of Chree analysis of BDE and MCE events with solar wind components, such as bulk flow speed, ion density and proton temperature on left and right panels respectively. These two events are associated w'.h coronal holes. Zero days on the time scale corresponds to the beginning of the event. Coronal holes associated BDE's show significant increase in solar wind velocity and proton temperature.

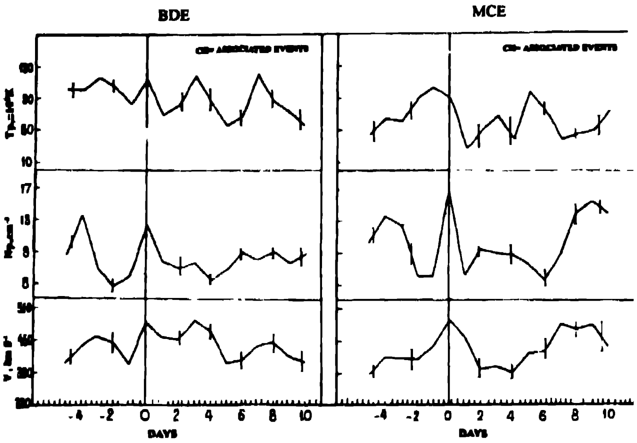

Figure 1. Superposed epoch analysis of the plasma parameters *i.e* solar wind velocity V (km s^{-1}), ion density N_p (cm^{-3}), proton temperature $T_p \times 10^3$ (K°) in transient disturbances of two types : BDE (left) and MCE (right), Coronal holes—associated events.

Both show transient enhancements lasting six to seven days after the zero days. Ion density decreases immediately after the occurrence of the event. However, on the other hand, results of Chree analysis of coronal hole associated MCE's show different effects on solar wind velocity as shown in Figure 1 (right panel). An enhanced bulk solar wind velocity and ion density on the onset of the event day is evident. Proton temperature does not provide any meaningful result except a sharp decrease on the first day after the event day. Hence, it is concluded that the bi-directional events (BDE's) are more effective to produce increase in solar wind velocity as well as for transient fluctuations in ion temperature than the events of magnetic clouds (MCE's).

Further, we have performed the Chree analysis to observe the effect of BDE's and MCE's that are not associated with coronal holes. Results are shown in Figure 2. The BDE's show a maximum solar wind speed on the event day, which starts increasing before 1 day of the event, goes to maximum, then decreases sharply taking 5 days on the time scale. Similarly, the ion density and temperature starts increasing before one day and after having the maximum values on the event day decrease continuously for the following next day. Similar results for solar wind velocity are observed for MCE's without coronal hole associated events. However, density values are found minimum upto four days after the zero epoch day. Fluctuations are seen for the proton temperature. Here, we can conclude that only coronal hole associated magnetic cloud events are found responsible to produce significant decrease in the solar wind velocity on short-term basis.

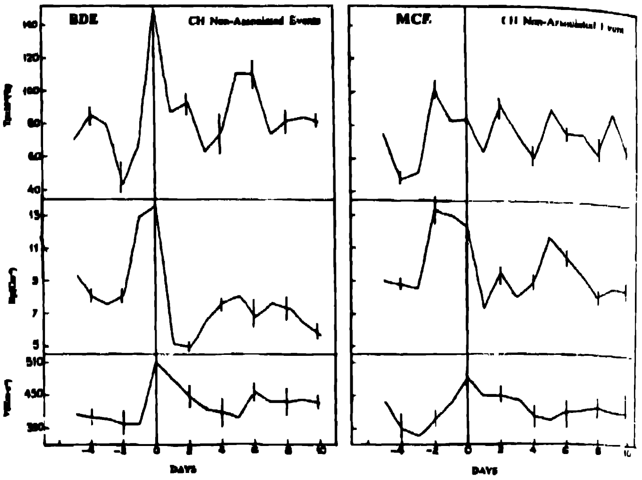

Figure 2. Superposed epoch analysis of the plasma parameters *i e.* solar wind velocity V (km s^{-1}), ion density N_p (cm^{-3}), proton temperature $T_p \times 10^3$ (K°) in transient disturbances of two types : BDE (left) and MCE (right), these events are not associated with coronal holes.

Figure 3 shows the effects of these two types of transient variations on cosmic ray intensity on short-term basis. Slight

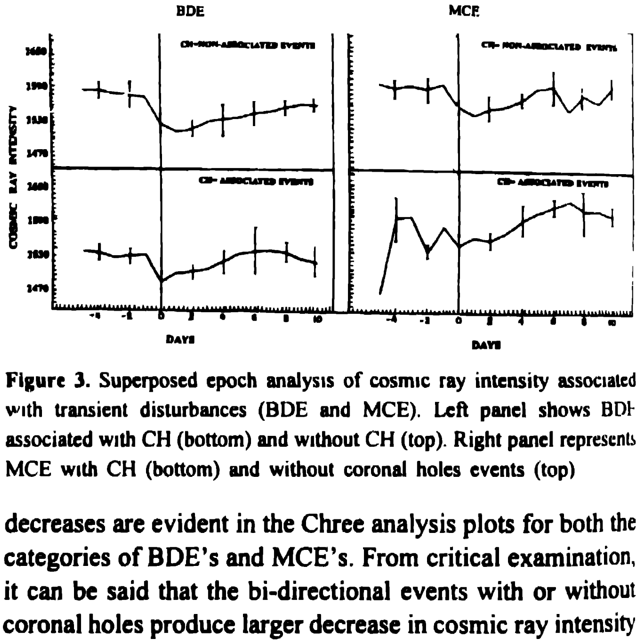

Figure 3. Superposed epoch analysis of cosmic ray intensity associated with transient disturbances (BDE and MCE). Left panel shows BDE associated with CH (bottom) and without CH (top). Right panel represents MCE with CH (bottom) and without coronal holes events (top)

decreases are evident in the Chree analysis plots for both the categories of BDE's and MCE's. From critical examination, it can be said that the bi-directional events with or without coronal holes produce larger decrease in cosmic ray intensity than the magnetic cloud events. Hence, we can infer that coronal holes are not a prominent factor to produce decrease in cosmic ray intensity.

On comparing averaged relationship of plasma parameters for MCE and BDE from Figures 1 and 2, it is found that the characteristics of these two types of transient disturbances in association with coronal holes or without coronal holes association, differ appreciably in plasma velocity and temperature. An increase in the solar wind plasma velocity in the BDE with CH case is about 50% larger than those for MCE and CH case. MCE and BDE without CH only show slight differences in proton temperature where BDE without CH produce 40% large decrease in comparison to MCE without CH events. However, other investigators have reported different magnetic field characteristics in these two types of transient disturbances (BDE and MCE) [1]. The magnitude of the magnetic field in the sheath region in MCE increases as one approaches the MC boundary, while in BDE, immediately in front of BEHF boundary, the magnetic field decreases. Larger and varying magnetic field during the period of MCE's, certainly produce decrease in solar wind plasma velocity as well as in the intensity of cosmic rays. Therefore, increase in plasma velocity is associated with bi-directional events accompanied with coronal holes.

It may be concluded from the analysis that :

1. Bi-directional events associated with coronal holes are found to be responsible for producing increase in solar wind plasma velocity on short-term basis.
2. The magnetic cloud events do not produce any significant charge in plasma components.
3. Both types of transient disturbances are found responsible factors in producing decrease in cosmic ray intensity on short-term basis.

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