Cosmic ray intensity variation on the onset of interplanetary magnetic clouds

REKHA AGARWAL MISHRA [1], RAJESH K. MISHRA [2], M. K. RICHHARIA [1], M. P. YADAV [3]
[1] *Department of Physics, Govt. Model Science College (Autonomous), Jabalpur (M.P.) 482 001, India*
[2] *Computer and IT Section, Tropical Forest Research Institute, P.O.: RFRC, Mandla Road, Jabalpur (M.P.) 482 021, India*
[3] *Department of physics, Govt. Tilak P. G. College, Katni (M.P.) 483501, India*
contact. rkm_30@yahoo.com

Abstract: An investigation has been made so as to study the cosmic-ray decreases occurring during 2006 with respect to the arrival times of interplanetary shocks and magnetic clouds. We have identified three interplanetary magnetic cloud events during 5, February 2006, 13 April 2006 and 14 April 2006. The interplanetary magnetic field (B), north south component of interplanetary magnetic field (Bz), solar wind velocity, sunspot number (R) and disturbance storm time index (Dst) associated with these events has been studied in the present work. The data (neutron monitor count rate) from Newark Neutron Monitor 9NM64 has been used. The north south component of IMF (Bz) produce large geomagnetic disturbance on the onset of interplanetary magnetic clouds. The deviations in the interplanetary and solar wind plasma parameters are significantly correlated to the magnetic cloud events. The increase in Dst index, sunspot number (R) and Bz after the magnetic cloud event produces increase in cosmic ray intensity.

Introduction

Interplanetary magnetic clouds belong to one of the several classes of transient flows in the solar wind. Magnetic clouds as ideal force free objects (cylinders or spheres) are ejected near the sun and followed beyond the Earths orbit. It is found that the decrease in cosmic ray intensity, which are associated with magnetic cloud preceded by a shock, are very high and these decrease starts few days earlier than the arrival of cloud at Earth. From the study of the time profile of these decrease, it is found that the onset time of a Forbush type decrease produced by a shock associated cloud starts nearly at the time of arrival of the shock front at the Earth [1-2] and the recovery is almost complete with in a week.

Nowadays, the analysis of spacecraft data reveals that these events are common in the solar wind. About 30% of coronal mass ejections (CMEs) observed in the solar wind exhibit internal field rotations, characteristic of magnetic flux rope. However, the relationship between the CMEs observed near the Sun and magnetic clouds is poorly understood.

Forbush decreases associated with shock-associated cloud are caused by magnetic field variations associated with interplanetary disturbances [2]. Badruddin et al. [3] have reported a possible correlation between magnetic clouds and cosmic ray intensity decrease while Kudo et al. [4] have reported an increases in cosmic ray intensity that may be related to the geomagnetic D_{st} index and Iucci et al. [5] have found short term increase in CR intensity occurring inside the Forbush decrease, that possible may be associated with magnetic clouds. Zhang and Burlaga [6] infer that the cosmic rays are mainly modulated by fluctuation rather than by drifting in the strong smooth field in the magnetic cloud.

The magnetic clouds can interact with other flows [7]. Magnetic clouds are ideal objects for solar terrestrial studies because of their simplicity and extended intervals of southward and northward magnetic fields [8]. Gosling [9] has shown that approximately 1/3 of interplanetary manifestations of solar ejecta (also called CMEs by some authors) are magnetic clouds. A magnetic cloud like a well defined CME acts as a driver and forms a driver shock wave; propagation and properties of the shock and driver it self. Hence like interplanetary shock, magnetic clouds provide us with a link between ejected material, field and energy on the sun and significant magneto spheric activity via solar wind.

These events are not always associated with interplanetary shocks but only when they travel faster than the ambient solar wind. Besides the identification of magnetic clouds locating cloud boundaries is an open problem Lepping et al., [10]. Zhang and Burlaga [6] showed that the clouds are usually spatially shorter than the interval defined by counter-streaming electrons, suggesting that the clouds are parts of larger transient structures.

Many workers have shown the structure and dynamics of interplanetary magnetic clouds and their effects on the magneto sheath and magnetosphere. The association of geomagnetic activity to magnetic clouds and other IMF features are given by Farrugia et al. [10] and Tsurutani and Gonzalez [11]. Farrugia et al. [12] have shown that a major geomagnetic storm and associated aurora were produced by the extended interval of the negative B_z in the front part of magnetic cloud. As the magnetic cloud moved past the Earth, the magnetic field slowly rotated northward giving an extended interval with positive B_z in which the geomagnetic activity subsided.

Data and analysis

The temperature and pressure corrected hourly data (counts of neutrons) of cosmic ray intensity from Newark Neutron Monitor (Latitude 39.70N, Longitude 75.70W, Altitude 50 m, Standard pressure 1000 mb, Geomagnetic cut-off rigidity 2.09 GV) have been used, where the long-term change from the data has been removed by the method of trend correction. The days of Forbush decreases have also been removed from the analysis to avoid their influence in cosmic ray variation. Interplanetary magnetic field and solar wind plasma data have been taken from the interplanetary medium data book.

Results and Discussion

The influence of interplanetary magnetic clouds on cosmic ray intensity and various heliospheric parameters is very complex and hence needs detailed investigations. In the present work we have identified three interplanetary magnetic clouds during the year 2006 to study their effect on cosmic ray intensity variation, geomagnetic field and interplanetary parameters. Using the methodology of Zhang and Burlaga [6] we have identified three interplanetary magnetic cloud events (5, February 2006, 13 April 2006 and 14 April 2006) during 2006 to study their influence on interplanetary, solar wind plasma as well as on cosmic ray intensity.

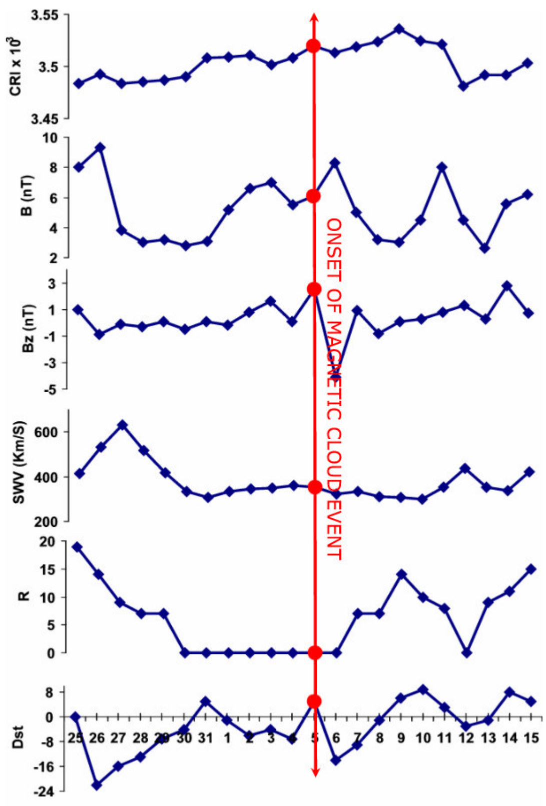

Fig 1: Daily variation of cosmic rays from -11 to +10 day for the magnetic cloud event of February 5, 2006 alongwith interplanetary magnetic field (B), north-south component of interplanetary magnetic field (Bz), solar wind velocity, sunspot numbers (R), disturbance time index (Dst).

Figure 1 represents the magnetic cloud event of February 5, 2006. The onset time of magnetic cloud is 1910 Hr UT on day 036. In Fig 1 the upper panel (a) shows the daily average of hourly cosmic ray count rate (Newark neutron monitor) from January 25, 2006 to February 15, 2006 i.e. 11 days prior and 10 days after the onset of magnetic cloud event. The daily average of interplanetary magnetic field (B), north south component of interplanetary magnetic field (Bz), solar wind velocity, sunspot number (R) and disturbance storm time index (Dst) associated with this event is also plotted in different panels of the figure.

As one can see from the plot that the cosmic ray intensity is observed to increase 11 days prior to onset of magnetic cloud event and then decrease for one day and further increases for few days and decreases significantly on February 12, 2006 with some deviations. The interplanetary magnetic field B is increases significantly from 6 days prior to 1 day after the event with some depression on February 4, 2006 then decrease significantly up to 4 days after the event. The systematic variations are seen in the Bz component of interplanetary magnetic field 11 days prior to the event upto the onset of magnetic cloud and then decrease significantly after one day of the event and then increase significantly up to 2 day after the event and then systematic variations continued up to 10 days after the event.

The solar wind velocity is seems to remain constant before and after 5 days of the onset of magnetic cloud. The sunspot number (R) significantly decreases 11 days prior to the event 6 days prior to the event and then significantly remains constant upto 1 day after the event. The abrupt change is observed in the sunspot numbers after 1 day of the onset of magnetic cloud. The disturbance time index, Dst is found to increase significantly 10 days prior to the event up to 5 days prior to the event and then decreases upto 1 day prior to the event. On the onset of magnetic cloud the Dst decreases significantly for 1 day and then increase upto 5 days after the event.

It is noted that on the onset of magnetic cloud the cosmic ray intensity, Bz component of IMF, Disturbance storm time index Dst found to decrease for one day and then all the three components increases gradually, whereas interplanetary magnetic field B increases for one day and then decrease sharply. However the solar wind velocity found to remain constant and sunspot number (R) increases after one day of the onset of cloud with some depression.

The disturbance storm time index (Dst) has been taken as a level of geomagnetic disturbance. North south component of interplanetary magnetic field Bz turns southward immediately after the magnetic cloud event. This southward turning of Bz produces large geomagnetic disturbances, which reflects in Dst value. Increase in Dst index, sunspot number (R) and Bz after the magnetic cloud event seems to be associated with cosmic ray intensity increase. We have rigorously studied all the three magnetic clouds and found the similar trends in all the cases.

Conclusions

From the present investigations following conclusions may be drawn:

- The north south component of IMF (Bz) produce large geomagnetic disturbance on the onset of interplanetary magnetic cloud.
- The deviations in the interplanetary and solar wind plasma parameters are significantly correlated to the magnetic cloud events.
- The increase in Dst index, sunspot number (R) and Bz after the magnetic cloud event produces increase in cosmic ray intensity.

Acknowledgements

The authors are indebted to various experimental groups, in particular, Prof. Margret D. Wilson, Prof. K. Nagashima, Miss. Aoi Inoue and Prof. J. H. King for providing the data.

References

[1] S. P. Duggal, M.A. Pomerantz, R.K. Schaefer, and C. H. Tsao, J. Geophys.

Res., 88, 2973, 1983.

[2] Badruddin, R. S. Yadav, N. R. Yadav, Solar Phys., 105, 413, 1986.

[3] Badruddin, R. S. Yadav, and S. P. Agrawal, Proc. 19th, Int. cosmic ray conf., SH-5, 1-12 NASA Cof. Publ., 258, 2376, 1985.

[4] S. Kudo, M. Wada, P. Tanskanen, and M. Kodama, 19th, Int. cosmic ray conf. SH5, 1-8 NASA conf. Publ., 2376, 246, 1985.

[5] N. Iucci, M. Parisi, C. Signorini, M. Storini, and G. Villoresi, 19th. Int cosmic ray conf. Publ., 2376, 226, 1985.

[6] Z. Zhang, and L. F. Burlaga, J. Geophys. Res., 93, 2511, 1988.

[7] L. F. Burlaga, International Magnetohydrodynamics, Oxford Univ. Press, New York, 1995.

[8] L. F. Burlaga, R. Lepping, and J. Jones, Geophys. Monogr. Series, Vol. 58, 373, 1990.

[9] J. T. Gosling, Geophys., Monogram, 58, 343, 1990.

[10] R. P. Lepping, L. F. Burlaga, and J. A. Jones, J. Geophys. Res., 95, 11957, 1990.

[11] C. J. Farrugia, L. F. Burlaga, and R. P. Lepping, Geophys. Monogr. Series. Ed. By Tsurutani et al., 1997

[12] B. T. Tsurutani, and W. D. Gonzalez, The Interplanetary causes of magnetic stroms, a Rev. in Geophys. Monogr. Series, 1997.

[13] C. J. Farrugia, R. P. Lepping, L. F. Burlaga, A. Szabo, D. Vassiliadis, P. Stauning, and M. P. Freeman, EOS, Trans. AUG. 77(17), Spring Meet. Suppl., S2 41, 1996.