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Coronal hole and CME-associated solar wind streams and their effects on cosmic ray intensity

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Abstract: Solar wind streams from coronal holes and those associated with coronal mass ejections have been identified. Using superposed epoch analysis, we analyze the cosmic ray neutron monitor data and solar wind plasma/field data with respect to two types of streams. We find a large difference in the cosmic ray response to the streams of different origin. The observed difference in the amplitude and the time profile of cosmic ray intensity is compared to the variations in solar wind parameters, particularly plasma speed, temperature and density and field strength. We also attempt to search for the cause of this difference in response, by analyzing the plasma and field data during the passage two types of streams of different solar origin.

Introduction

One of the most spectacular advances of space era is the discovery of coronal mass ejection (CMEs) in which large amounts of solar material are propelled outward into interplanetary space with great speed from closed field region [e.g. 1,2]. Coronal holes (CH), on the other hand, are open field regions emitting high speed solar wind streams. Streams originating from coronal holes are believed to be corotating while those associated with CMEs are transient streams.

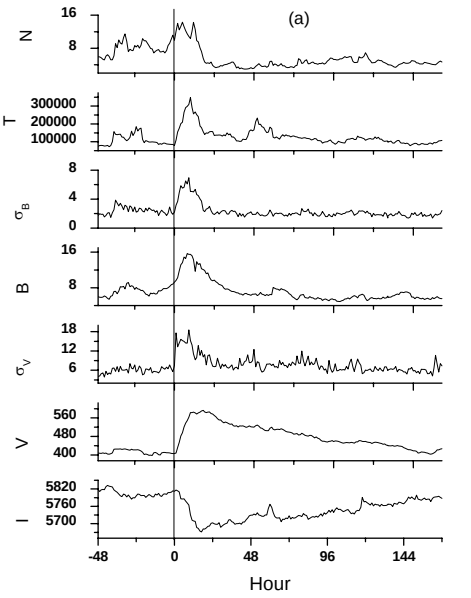
The interaction of the solar wind with the cosmic rays is complex and the phenomenology of interaction is likely to be different for solar wind dominated by transient ejecta (e.g. CMEs) compared to solar wind dominated by high speed streams from open field regions of coronol holes [e.g. 3-7].

On the basis of their origin, two types of streams are identified during the period 2001-2004 and selected the streams with no data gap. We have considered these two categories of streams of different origin on the Sun and studied their effects on cosmic ray intensity using the superposed epoch analysis. Hourly cosmic ray neutron monitor data together with the solar plasma and field data (solar plasma speed V, RMS standard deviation in V, IMF vector B, RMS standard deviation in B, plasma temperature T and density N) have been subjected to superposed epoch analysis with respect to arrival time of the two types of streams.

Results

In Fig. 1(a, b) we have plotted the results of superposed epoch analysis of solar plasma and field variations with respect to CME-associated and CH-associated streams along with the resulting variations in cosmic ray intensity. The plasma and field parameters considered for the analysis are: the speed (V), temperature (T), density (N), and field strength (B); RMS standard deviations in V (sigma V) and B (sigma B) are also plotted.

From a comparison of these two figures we see the CME-associated streams are much effective in modulating the cosmic ray intensity. The decrease due to CME-associated streams is Forbush-decrease and the effects of CH-associated streams are slow depressions in intensity of smaller amplitude and longer duration.



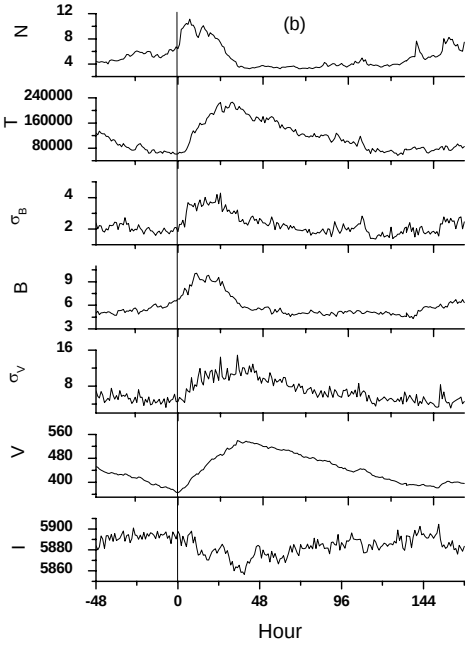
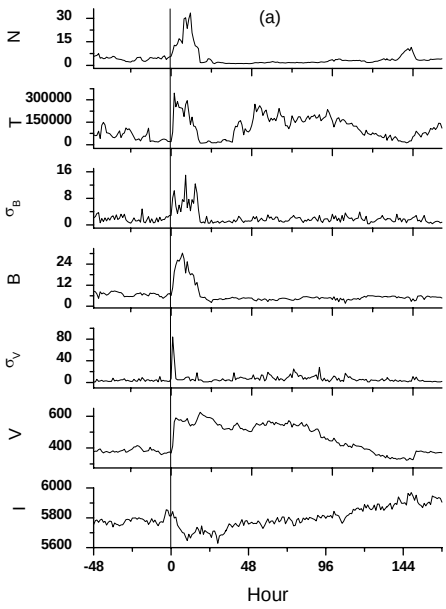


Figure 1: Superposed epoch analysis results of cosmic ray intensity (Oulu neutron monitor data) and solar wind plasma/field parameters with respect to arrival of (a) CME-associated and (b) CH-associated streams.



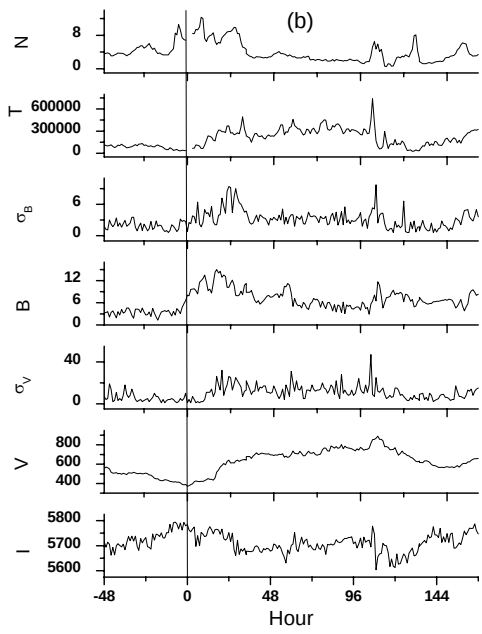


Figure 2: Two typical events showing variations in cosmic ray intensity and solar plasma/field parameters with respect to arrival of (a) CME-associated and (b) CH-associated streams.

Comparison of the plasma and field parameters associated with two types of streams reveals differences not only in their amplitude (Table-1) but also their time profiles during arrival/passage of the streams. There are sudden jumps in almost all parameters at the arrival time of CME-associated streams, while due to CH-associated streams, these parameters start increasing slowly and reach to maximum value in comparatively larger time before they start decreasing towards their normal values. The jumps in sigma V and sigma B are particularly sharp at the time of the onset of Forbush-type decrease.

Table-1: Comparison of maximum values of different parameters due to streams of different origin and resulting decrease in cosmic ray intensity.

Streams association	ΔI	V	σ_V	B	σ_B
CH	0.7	539	14.9	10.0	4.3
CME	2.4	593	18.5	15.7	6.9

A typical event each due to CME-associated and CH-associated stream is also shown in Fig. 2(a, b). The variations in different parameters during these events are further illustrative of the results discussed on the basis of superposed epoch analysis.

Conclusions

CME-associated solar wind streams are much more effective in modulating cosmic rays than CH-associated streams.

The decreases in cosmic ray intensity due to CME-associated streams are Forbush-type while those due to CH-associated streams are slow depressions in intensity with much smaller amplitude.

The solar wind parameters show a sharp increase at the arrival of CME-associated streams while CH-associated streams rise slowly to attain their peak values. In particular, the enhancement in sigma V and sigma B are very sharp in the former case.

On the average, the amplitudes of solar wind parameters (B, T, N) are larger in case of CME-associated streams.

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