Distinctive Characteristics of Solar Wind Streams with regard to Cosmic Ray Intensity & Geomagnetic Field Variation

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Large solar wind streams observed recently have been classified into two groups, for the period 1968-1975, on the basis of their association with the solar flare, assuming that the velocity remains constant during sun-earth transit. Both the groups of streams are then separately related with the changes in the cosmic ray intensity and geomagnetic field. It is found that the streams associated with solar flare are very effective in producing cosmic ray intensity decreases as well as geomagnetic field variations; whereas the other group of streams which are not associated with any solar flare, produce only geomagnetic field variations and do not exhibit any cosmic ray intensity changes. The results are discussed in the light of recent observations of coronal holes and their association with the solar wind.

1. Introduction

It has long been recognized that both the decrease in cosmic ray intensity and large fluctuation in geomagnetic field have their common source of origin at the sun. The quiet time solar wind of ambient speed \( \approx 300-400 \) km/sec is found, many a time, to show structures for a few days in the form of high velocity solar wind streams. These results are now available since 1962. Recently, a number of workers\(^1\)\(^-\)\(^5\) have established strong positive correlation between the solar wind velocity and geomagnetic field variations as measured by \( \Sigma K_p \) or \( A_p \) indices. However, the correlation with the cosmic ray intensity is quite small. In a number of cases it has been observed that a high velocity solar wind stream produces large geomagnetic field fluctuations, whereas no significant effect is seen in cosmic ray intensity. Recently, Dryer and co-workers\(^6\)\(^-\)\(^7\) have reviewed the theoretical and experimental aspects of the effect of shock waves generated during intense solar flare. They observed that the high velocity solar wind streams associated with the shock wave generally produce major geomagnetic field fluctuation as well as large decrease in cosmic ray intensity. Further attempts to correlate various interplanetary plasma and field values with the cosmic ray intensity and geomagnetic field could not provide any unique parameter to explain the observations.\(^6\)\(^-\)\(^7\)\(^-\)\(^10\) Since almost continuous data are now available for the solar wind velocity,\(^11\) it is instructive to select high velocity solar wind streams so as to find their influence on the cosmic ray intensity. During the course of the investigation, it has been found that almost half of the high velocity solar wind streams are not effective in producing the cosmic ray intensity variations, whereas all streams have equal probability in affecting the geomagnetic field.

2. Stream Identification

In this study only those solar wind streams have been considered for which the solar wind velocity increases to more than 400 km/sec,\(^11\) and remains so, for at least 2 days. Further, the initial increasing gradient should be \( > 100 \) km/sec/day at the head of the stream. Starting from the year 1968 and continuing up to 1975, we have selected 116 streams satisfying the above conditions. By computing the average speed of each stream for the period of high velocity with low gradient, we have obtained the time of the origin at sun of the strata of each of these high velocity stream. From this computation it has been possible to know the solar condition at the time of emission of each stream. It is noticed that the origin of many (but not all) of the streams are in time coincidence (± 12 hours) with the eruption of the solar flare. Therefore, all the events have been classified into two groups, i.e. (i) streams associated with solar flares (ii) streams not-associated with any solar flare of importance \( \geq 1 \)B. It was observed that out of 116 streams 65 streams are associated with the solar flares.
3. Results and Discussion

The two distinct types of high velocity solar wind streams, as identified above, have been associated separately with the geomagnetic field variations and cosmic ray intensity decreases. For each of the two groups, the cross-plots have been drawn separately between average solar wind velocity in the streams and (i) the value of the respective geomagnetic field index $\Delta K_p$ (Fig. 1), and (ii) the cosmic ray intensity decrease (Fig. 2).

From Fig. 1, it is noticed that both the types of solar wind streams are equally effective in producing geomagnetic field variations in agreement with the earlier results. However, the same is not true for cosmic ray variations. Fig. 2 shows that only those solar wind streams which have been produced in association with the solar flare are responsible for significant cosmic ray decreases. Fig. 2 also shows that the solar wind streams which are not associated with the solar flares are incapable of producing any large cosmic ray decrease. The results of our investigation, for the first time, very distinctly differentiate the two types of characteristic features of solar wind streams. These results are understandable in the light of the hypothesis proposed by Hundhausen, where it has been emphasized that the two different types of shock fronts produce different effects on the physical conditions of interplanetary space. The first type of shock front which is associated with both energy and mass is capable of producing both large geomagnetic field disturbances and the cosmic ray decreases. The other type of wind streams, which essentially contains energy might have its source of origin on the coronal holes. These coronal regions

4. Conclusions

(i) There are two distinctly different types of high velocity solar wind streams near earth, apparently looking similar, viz. (a), those which are in time association with the solar flare and (b), those which are not associated with any solar flare of importance $\geq 1B$ on the visible disk of the sun.

(ii) Both types of stream produce almost similar effect on geomagnetic field variations. The value of $\Delta K_p$ or $A_p$ increases in both the cases.

(iii) The solar-flare associated streams are most effective in producing cosmic ray decreases, whereas the flare not-associated streams, if at all, produce decreases that are of very small magnitudes.

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References