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Manifestation of shock wave orientation in the cosmic ray intensity and geomagnetic field decrease

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Abstract. In our study, such an approach is developed to reveal the connection of the shock geometry and it's normal orientation. The comparison of cosmic ray and geomagnetic field measurements has been carried out during the passes of the shock with determined normal characteristics calculated by multiple spacecraft data. It was showed that the angle between shock normal and solar wind bulk speed is corresponded to different locations of the spacecraft relatively the disturbed region. Taking into account unspherical form of the solar wind structures, the results are used for the curvature radius evaluation. Thus, an usefulness of joint analysis of cosmic ray and geomagnetic data for diagnostics of the interplanetary disturbance structure has been verified.

1 Introduction

In spite of extensive in situ studies of the solar wind disturbances structure and geometry, the association between interplanetary disturbances and their ground manifestations is not completely understood yet. At present a great number of multiple spacecraft data allows to solve this problem taking into consideration the interrelations of there form and structural peculiarities (St.Cyr et al., 1999; Cane et al., 1994). So, in Lindsay et al. (1999); Russell et al. (1983, 2000) it was shown that a considerable errors in shock normal characteristic determination using a multiple spacecraft data remains to be the uncertain form of a solar wind disturbance.

We consider that the attraction of the ground-based observations of cosmic ray (CR) and geomagnetic field intensity allows to obtain necessary information on the geometry of the solar wind disturbance and, therefore, on the shock form.

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2 Determination of the Geometry of the Shock Intersection

In this paper we have analyzed the 6 events from Russell et al. (1983, 2000) where the determination of the shock orientation was fulfilled using different examination methods of multiple spacecraft data. In order to construct the overall picture these results have been compared with the ground-based CR intensity and geomagnetic field observations in the frame of so-called Forbush-storm classification (Shadrina et al., 1996).

According to this classification, the interplanetary disturbance geoeffectiveness in a considerable degree differs for the flank and central intersections. The sketch illustrating a possible interplanetary disturbance topology for the producing four ground classes is presented in Figure 1. In the case of central passages of the Earth through the solar wind disturbance both Forbush-decreases (FD) and geomagnetic storms (MS) occur - the class "FD and MS". This class of events are quite well studied. During the flank intersections the value of the ground effects is essentially less. But chiefly during the west intersections the CR decreases without the geomagnetic field depressions occur - the class "FD, no MS". During the east intersections geomagnetic storms without visible effects in CR occur or even the decreases in CR and in the geomagnetic field are not observed at all - the classes "MS, no FD" and "no FD, no MS".

The width of every sector in Figure 1 corresponds to the frequency of the occurrence of every class of the events: I - "FD, no MS", II - "FD and MS", III - "MS, no FD", IV - "no FD, no MS". By our opinion, the reason of this difference of the solar wind disturbance flank geoeffectiveness consists in a well-known east-west asymmetry of the Forbush-effects: the amplitude from east flares is considerably higher than from the west ones.

It means that the region with the lower contents of the CR - the FD-region - is displaced to the west edge of the disturbance region. This is consistent with the data on the IMF configuration: for the east flares a quasiperpendicular config-

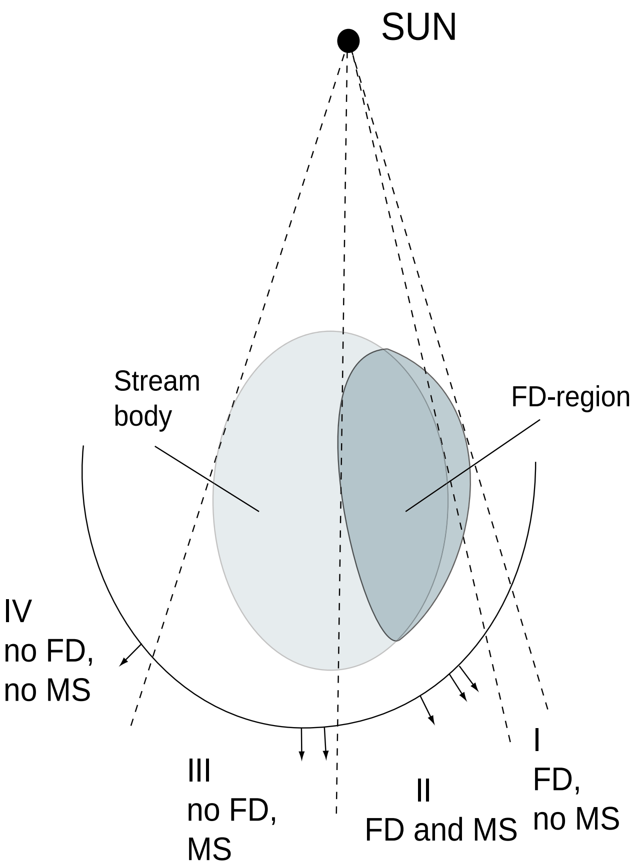

Fig. 1. The sketch illustrating a possible interplanetary disturbance topology for the producing four ground Forbush-storm classes. FD–region is the region where the CR contents is fell down. Because of the FD–region does not coincide with the stream body region, the trajectories of the interplanetary distturbance may pass through the Earth in sectors I, II, III or IV.

uration of IMF is peculiar, and for the west one - the quasi-parallel configuration (Pudovkin and Bogdanova, 2000) . We have tried to illustrate this in Figure 1: the stream body region (the region with the increased plasma speed, or CME) is located in the central part of the disturbance region and the FD–region is displaced to the west edge of the disturbance region.

Thereby the existence of four ground disturbance classes may be explained by west, central or east passages of the Earth through one of the structures, or through both of them, or past both of them. According to the sketch from Figure 1, four sectors are corresponded to four ground disturbance classes. These sectors may be described by one parameter — an angle ϕ between the radial direction to the Sun and the normal to the shock in the point of the intersection of the solar wind disturbance by the Earth.

For the known characteristics of the shock normal we assigned mathematically a model of the shock form and determined the angle ϕ and intersection point location for all 5 events from Table 1. The model has two free parameters: the shock curvature radius and its displacement with respect to the stream body.

The results are shown in Table 1, and 6 vectors, representing the normals for chosen 6 events are marked in Figure 1. Every vector corresponds to an event from Table 1: extremely right vector is the event number 1, and in such a manner clockwise to the extremely left one — the event number 6. The dates and onset time of every event and GSE–coordinates of the shock normal calculated in Russell et al. (1983, 2000) are represented in Table 1.

The disturbance class of the expected ground event have been determined by sector, in which the normal vector appeared to be present (or by the point of the disturbance region intersection). This class is located in column ”Class N” in Table 1. Further, knowing the date, the real ground event class has been determined by the facts of the occurrence or absence of the magnetic storms and CR intensity decreases at Earth. This information is located in columns ”MS”, ”FD” and ”Class SF” in Table 1. At the last column of Table 1 there is sign ”+”, if classes in ”Class N” and ”Class SF” coincided, sign ”0” if the classes, determined by two methods were neighboring, sign ”-” if the classes did not coincide at all.

As it is seen from Table 1, in 5 events the classes coincided, in 1 event there were the neighboring classes, and there were no events with not coincident classes. It is a very good agreement in spite of sufficiently large inaccuracy both in the normal orientation calculation (Russell et al., 1983, 2000) and in the intersection point determination (angle ϕ) by the mathematical simplified model.

It is necessary to note, that such a good agreement was achieved if the shock front curvature radius was equal to 0.5 AU in modeling calculations and the displacement between the FD-region and stream body was less than 10 degrees. Qualitatively the last value consents to the result of Zastenker et al. (1978) where it was shown the shock speed is maximal near the central meridian and falls down more slowly to the east flank of the shock than to the west one. That is, the shock front moves more rapidly along the field line than across it. Moreover, since the shock front curvature radius is twice as less of 1 AU, the shock form should not be a sphere centered at Sun. We consider, these facts are an evidence of unspherical form of the interplanetary disturbance.

3 Disscusion

So, the ground and multiple spacecraft data comparison allows to find:

— the angle between the shock front normal and solar radial direction in the point of its intersection by the Earth essentially depends on boundary curvature of the disturbance region in this point;

— the shock orientation may be used for the definition of the geoeffectiveness of the flank and central intersections of the disturbance region;

— the combined use of the CR and geomagnetic data for the definition of the geometrical factor of the Earth passing

ℵ	Date	Time, UT	Normal, GSE	ClassN	MS	FD	ClassSF	Resume
1	December 25, 1978	12:15	-0.802, -0.488, 0.344	II	+	+	II	+
2	August 18, 1978	12:39	-0.747, -0.433, 0.505	II	-	+	I	0
3	September 24, 1998	∼23:40	-0.981, -0.157, -0.112	II	+	+	II	+
4	September 11, 1978	08:57	-0.995, -0.134, 0.425	III	+	-	III	+
5	October 29, 1978	11:13	-0.893, 0.054, 0.447	III	+	-	III	+
6	August 31, 1979	05:55	-0.625, 0.287, -0.726	IV	-	-	IV	+

Table 1. The dates, onset time, shock normal components in GSE coordinate system and Forbush-storm classes, determined by two methods – using shock normal orientation and ground events in geomagnetic field (MS) and in CR (FD).

trough the solar wind disturbance region may be useful for the estimation of the shock curvature radius taking into account its unspherical form.

Thus, an usefulness of joint analysis of CR and geomagnetic data for the interplanetary disturbance structure diagnostics was confirmed.

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