ON REFLECTING BOUNDARY BEHIND THE EARTH'S ORBIT AT PROPAGATION OF FAST PARTICLES FROM SOLAR FLARES

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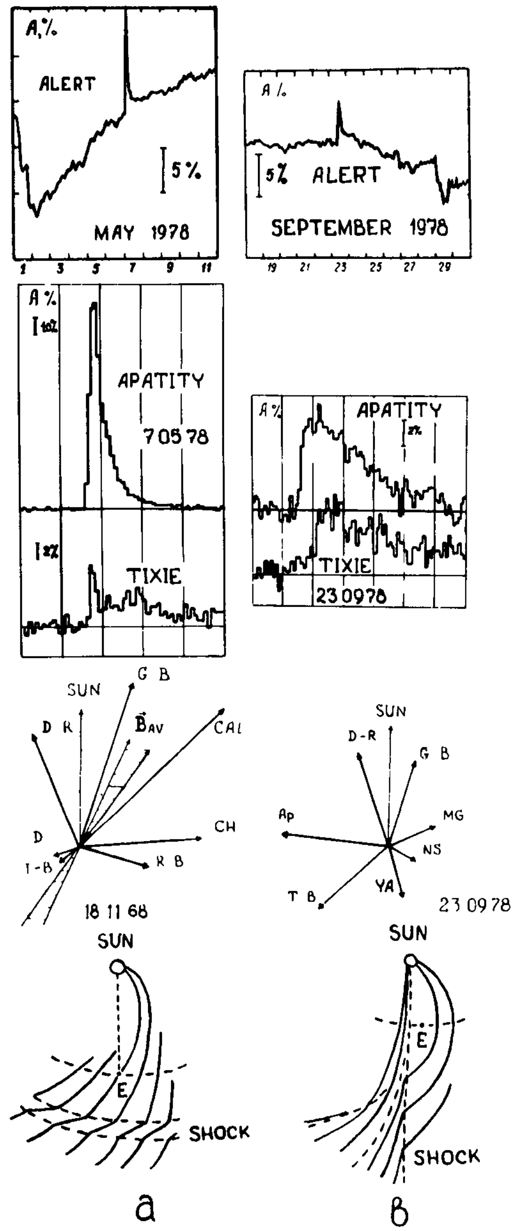
1. Introduction. The flares of solar cosmic rays (SCR) associated with the presence of shocks in interplanetary magnetic field and with their propagation at significant heliocentric distances were always of great interest 1,2 .

Here we consider some events and problems concerning the peculiarities of propagation of flare CR in the interplanetary medium. The distinguishing feature of such events is the presence of shock front behind the Earth's orbit having formed either directly in the process of shock generation on the Sun or at large heliocentric distances as a result of the interaction of fast and slow quasistationary recurrent solar wind (SW) streams. Based on the experimental material we show here that the significant nonlinear disturbances in IMF behind the Earth's orbit can yield the occurence of the additional SCR flux from shock front region as a result of the interaction of flare flux with shock and a partial reflection from it.

2. Method and Results. For the analysis on the available data of superneutron monitor net from all the solar proton events (SPE) for 1968-1984 were selected two main groups: the events at Forbush-decrease recovery phase associated with the passage of shock from the Sun and the events at GCR decrease phase associated with the passage of the interacting recurrent SW streams. The first group: 18,11.68, 07.08.72, 07.05.78, 12.10.81, 26.11.82; the second one: 25.02.69, 24-25.01.71, 30.04.76, 23.09.78. The identification of recurrent streams with small-amplitude Forbush-decreases was carried out on [3]. Only the events with reliable observational data were considered. In Figure are shown the examples from each group. Here are given the hourly intensity values for Alert (top) and 5-minute values for two stations having the oppositely directed "receiving cones" . Also are shown the asymptotic directions of particle arrival [4] for the following stations: Ap-Apatity, MG-Magadan, NS-Novosibirsk, Ya-Yakutsk, CAL-Calgary, D-R - Deep River, G-B - Goose Bay, CH-Churchill, D-Dallas, T-B - Tixie Bay, R-B - Resolute Bay. The length of vector is proportional to SCR increase amplitude. At the bottom is shown the qualitative picture of the reflecting boundary of two types. For all the events were built the analogous graphs and "receiving cones". The examples in Figure are typical for each group. In the Table are presented the onset time of increase (t_{ons}) for pairs of stations; the maximum ampli-

tude (A, %); the vertical cut-off rigidity (R_c); the mean angle between asymptotic longitudes of energetic particles arrival for pairs of stations ($\Delta\varphi$) and the mean φ_{me} angle between the direction of "Receiving cone" and the mean IMF direction in helioequator plane (OX-axis is sunward directed) for the station having the earlier time of increase onset. As is seen from the Table t_{ons} difference for the stations "looking" field-aligned sunward and in the opposite direction is significant and it reaches 30-40 min (for the event not under consideration here 16.02.84 it is ~ 60 min). The differences in A, % are also available.



3. Discussion. Similar delays for particles with E > 1 GeV can hardly be explained by the diffusion process within the Earth's orbit. Therefore one can assume that shocks accompanying all these events are responsible for the time difference of SCR intensity increase onset. I.e. the delay was caused by the fact that after the passage of shock beyond 1 a.u. the IMF becomes a regular one [5] and flare SCR injected in such a medium being not inclined in the Earth's magnetosphere pass behind its orbit and be reflected from the shock reverse front (for recurrent streams a higher regularity degree of IMF was shown in [6]). In favour of the such argument is a positive correlation between the duration of delay of SCR increase onset and the time between Forbush-decrease onset and flare onset (i.e. the farther is shock behind the Earth's orbit, the longer is the delay time). The calculations [1] show that on the average the reflected particles change their pitch-angle by ~ 20°. This value mainly is independent of the initial particle velocity or of shock parameters. We can conclude that the most SCR streams and shock interactions (reflections) are with no particle isotropization. If to try to recover the

Table

SPE	Station	t_{ons}, UT	A,%	R_c,GV	$\Delta\varphi$	φ_{mE}
18.11.68	Calgary Tixie Bay	1045 1105	17 2	1.07 0.45	~170°	~15°
07.08.72	Sanae Irkutsk	1525 1555	8 1.5	0.91 3.56	~170°	~15°
07.05.78	Apatity McMurdo	0330 0355	120 4	0.6 0.0	~180°	~15°
12.10.81	Irkutsk Magadan	0610 0640	4 7.7	3.56 2.11	~70°	-
26.11.82	Moscow Magadan	0250 0310	4 2	2.39 2.11	~180°	-
25.02.69	Goose Bay Tixie Bay	0920 0950	16 2	0.6 0.45	~170°	~15°
24.01.71	Inuvik Alert	2330 2340	14 15	0.16 0.0	~140°	~20°
30.04.76	Kerguelen Oulu	2125 2140	11 4	1.1 0.77	~110°	~45°
23.09.78	Apatity Novosibirsk	1030 1040	14 5	0.6 2.78	~150°	-

picture of intensity increase change on SPE at the station "looking" anti-sunward direction taking into account the presence of shock behind the Earth's orbit, one can obtain the following result: the particles of direct SCR stream from the Sun trapped by the Earth's magnetosphere (if their number is sufficient) will produce the insignificant "diffusive" intensity increase during the delay of two oppositely "looking" stations, then will occur a sharp intensity increase caused by the arrival of SCR stream reflected from the shock. The above view point explains qualitatively both groups of events. For more convincing evidence of existence of the reflected SCR component the energy spectrum of reflected particles is of great interest. But its finding is impossible yet because of lack of data on stations "looking" strictly in the direction of the arrival of the reflected component.

At a detailed investigation in groups of each event were found the peculiarities which can be explained not only by the presence of shock behind the Earth's orbit, but also by the existence of "corks" near the Sun caused by thickening of IMF force lines in the direction towards photosphere. The similar peculiarities were manifested in "two-humped" change of SCR intensity increase. The first increase corresponds to the reflection from shock behind the Earth's orbit and has a delay $\sim$ 20-25 min and the second one corresponds to the secondary reflection from the "cork" already with the delay ~ 50-60 min (such a phenomenon was observed for Tixie Bay on May 7, 1978).

4. Conclusion. From the above analysis one can conclude: it is most probable that for the peculiarities of SCR increase change in SPE on ground-based data (the delay of SCR increase onsets with E > 1 GeV at various stations; the significant difference in amplitudes; "two-humped" structure of increase etc) are responsible strong non-linear IMF disturbances (shocks) playing a role of the reflecting boundary for energetic particles.

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