PECULIARITIES OF PROPAGATION OF CHARGED PARTICLES IN SOLAR CORONA

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ABSTRACT

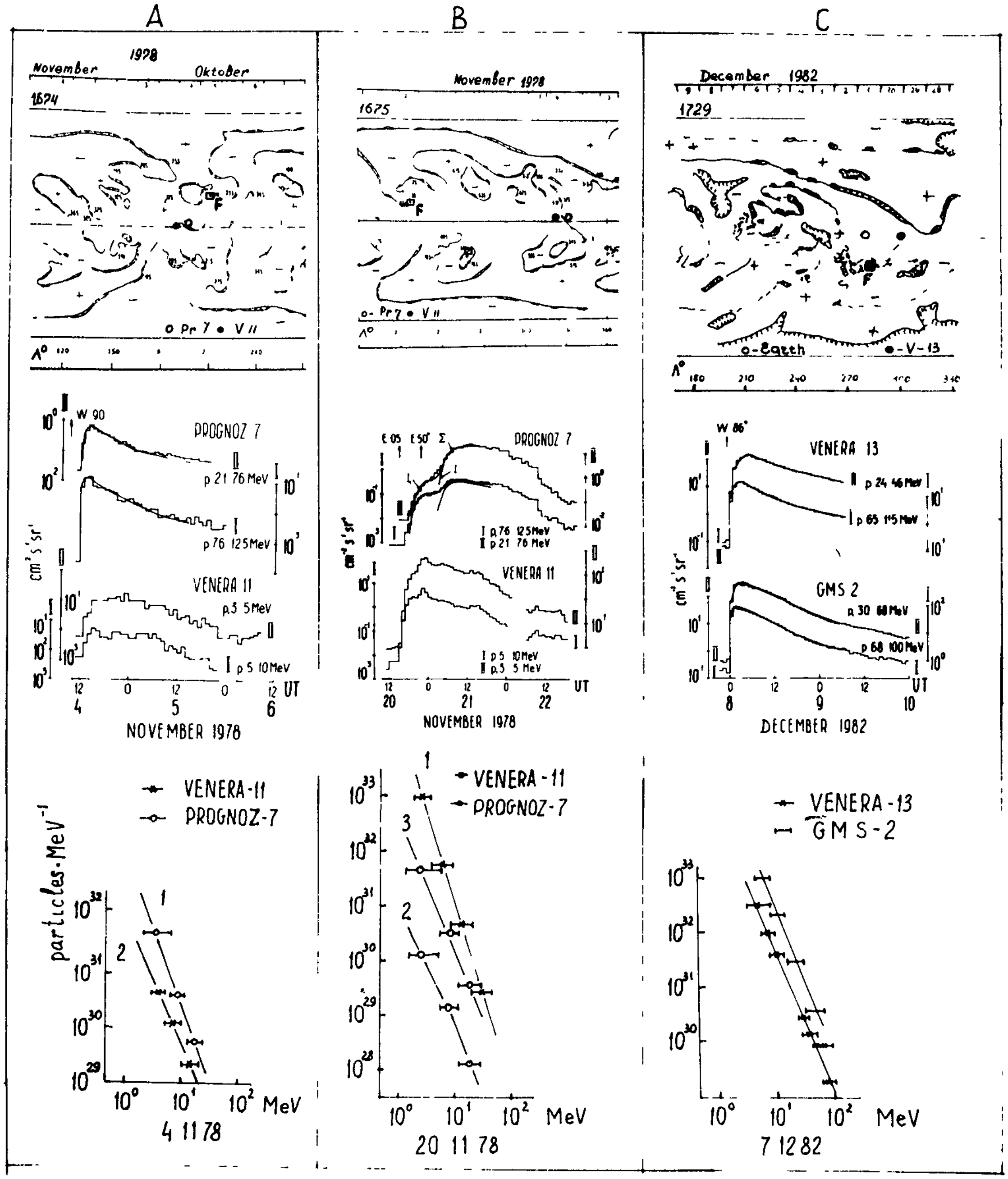
The influence of boundaries of the large-scale unipolar magnetic regions (UMR) on the Sun upon the charged particle propagation in the solar corona and interplanetary space is investigated. Increases of the charged particle fluxes from solar flares on November 4 and 20, 1978 detected by "Venera-11" and "Prognoz-7" and on December 7, 1982 by "Venera-13" and "GMS-2" were analyzed.

1. The investigations of a large number of solar flares located at various heliolongitudes revealed some regularity in dependence of time of the coronal particle transfer from the flare heliolongitude [1,2]. It was shown that out of the region of fast propagation of particles the speed of coronal transfer of particles is 17 - 40°/hr [2]. However, it is still unclear where the deceleration of a flux of particles propagating in corona occurs and with what the decrease of transfer speed is associated.

2. To estimate the influence of boundaries of the large-scale UMR upon temporal and spectral characteristics of charged particle fluxes the increases of fluxes associated with November 4 and 20, 1978 and December 7, 1982 solar flares were investigated (Figure). Each event was observed simultaneously at two spacecraft located at various azimuthal and radial distances from the Sun. In Figure the synoptical maps of photospheric magnetic fields are shown where ▫F are places of the flares [3]. Here the projections of force line bases (injection points) associated with spacecraft are shown. The points of connection on the Sun are calculated taking into account the average speed of solar wind on Prognoz-7 and IMP-8 data.

The injection moment of particles into the force tube connected with spacecraft was determined on [5]. On difference between moments of injection and generation of particles (maximum in H_α) the speed of particle flux transfer in the corona is estimated.

For 4.11.78 event the fast arrival of particles to the point of connection with Prognoz-7 (flare and point of connection are in one UMR) is observed and the transfer speed



is ~ 145°/hr. At the injection point Venera-11 (a connection point) a significant delay of particles is observed and an average particle transfer speed in the corona to the connection point with Venera-11 is only ~ 12°/hr. It is obvious that such a decrease of the average speed is caused by the particle propagation across the UMR boundary. Since the azimuthal distance between injection points Prognoz-7 and Venera-11 is ~ 8° the estimated transfer speed of particles across the UMR boundary is ~ 5°/hr.

In 20.11.78 event (Figure,B) for Venera-11 the moments of injection and generation of particles coincide. The injection point Venera-11 is at one UMR with the flare and the fast transfer of particles inside UMR is realized. The particles from the flare into the force tube connected with Prognoz-7 are injected twice. The first moment of the injection (1525 UT) is delayed with respect to the moment of generation by ~ 33 min which yields the speed of particle transfer in the corona to the injection point Prognoz-7 $\sim 135°$/hr. The second injection (the arrival of the main "mass" of particle flux) occured at 1725 UT and the average speed particle transfer in the corona to the injection point Prognoz-7 is $\sim 30°$/hr. Since the azimuthal distance between injection points Venera-11 and Prognoz-7 is $\sim 6°$ and they are located at various UMR near the boundary then the estimations of speed of particle flux transfer across the boundary yield $\sim 2.5°$/hr [4]. In 7.12.82 event (Figure, C) the place of the flare and the injection point for Venera-13 and GMS-2 are located in one UMR. The moments of generation and injection of particles within measurement errors coincide, i.e. the fast particle transfer in the corona is realized.

3. To determine a total number of particles at the injection point and to estimate the efficiency of the UMR boundary consider the propagation character of charged particles in the interplanetary medium. The location of force line bases connected with Venera-11 and Prognoz-7 (Figure,A,B) near UMR boundary determined significantly a complicated structure of temporal profiles of particle fluxes. UMR boundaries influence not only upon particle propagation in the solar corona but indirectly upon the character of particle propagation in the interplanetary medium. For instance, more complicated than in Prognoz-7 temporal structure of particle flux increase on Venera-11 was caused by a prolonged particle injection (for 4.11.78) into the force tube connected with Venera-11 and by a presence of large-scale interplanetary magnetic field structures near the UMR boundary (for 20.11.78). For illustration the temporal profiles of intensities only at two energy ranges (the average graphs of Figure,A,B,C) were chosen.

Temporal profiles of intensity were approximated by a solution of the diffusion equation [6]. The differential energy spectra of particles at injection points are presented in Figure, A,B,C, bottom. In Figure,A,B the curves 1 show spectra at injection point located in one UMR with flare (the fast particle transfer in the corona). The curves 2 are the spectra at injection point observed behind UMR boundary (the curve 3 transfer across the boundary). The curve 3 is the spectrum of particles propagating fastly across the UMR boundary.

A comparison of a total number of particles before and after the boundary allows to estimate its "transparency". For proton energies $E_p \sim 5$ MeV only $\sim 15\%$ (4.11.78) and $\sim 8\%$ (20.11.78) of a total particle flux penetrated across the boundary, for $E_p \sim 20$ MeV this value is $\sim 25\%$ (4.11.78) and

~ 20% (20.11.78). It is interesting to compare the absolute particle fluxes detected at injection points of Venera-11 and Prognoz-7 20.11.78 propagating fastly in the corona (curves 1 and 2, Figure, B). The ratio of these fluxes determines actually the efficiency of fast particle transfer across the UMR boundary. For $E_p \sim 5$ MeV only $\sim 0.3\%$ of particles is observed behind the boundary, for $E_p \sim 20$ MeV energies this value is $\sim 0.7\%$.

In the event of 7.12.82 (Figure,C) the absolute particle fluxes on GMS-2 are by an order of magnitude larger than on Venera-11. Here there are no influences of UMR boundaries upon charged particle transfer in the corona. Such a difference in a value of flux confirms the earlier found experimental fact [7] that on closed force lines of geomagnetic field ($L \sim 6.6$) the measured particle flux is larger than its values beyond the Earth's magnetosphere due to the isotropization effect.

4. Thus, the boundary of the UMR decreases significantly the effective speed of particle transfer in the corona. Within the UMR boundary the speed of particle transfer is $2 \div 5°$/hr. Only insignificant portion of flare particle flux propagates across the boundary without the change of the speed and density. At estimation of absolute values of particle fluxes from the flare it is necessary to take into account the influence of not only boundaries of large-scale UMR on the Sun but also the peculiarities of processes of interaction of particles with interplanetary and geomagnetic fields.

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