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# Solar cosmic rays in October – November 2003 and the particle acceleration by shocks in interplanetary medium in the October 28, 2003 event

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The events in cosmic rays in October – November 2003 by the Yakutsk detector complex and Tixie Bay station data using the world station network and in situ measurements of interplanetary magnetic field parameters are studied. The data analysis shows that these events by their features are similar to the known increases of SCR in July 1959, August 1972, October 1981 and in September – October 1989. As with these events, in October – November 2003 three increases of energetic particles on the Earth against the background of alternating Forbush – decreases are observed. In this connection, the increase of energetic particles on October 28, 2003 is of particular interest. The presence of shocks at that time essentially affects the process of diffusive particle propagation. In particular, the additional flux of relativistic particles after the maximum of flash particles is observed, which remains to be practically constant up to the arrival of a shock on the Earth. By data of in situ measurements of solar wind parameters, the passage of two shocks by the Earth with the velocities of 1000 and 1800 km/s took place. Thus, the additional flux of E>1 GeV particles is caused by the acceleration at shock fronts coming together.

## 1. Introduction

The passage of two active regions NOAA/SEC 10484 and 10486 through the solar disk was accompanied by flares with a generation of energetic particles with $E > 1$ GeV on October 28, 29 and November 2, 2003. The events took place at the background of Forbush-decreases on October 21, 24, 29, 31 and November 4 associated with the arrival of interplanetary shocks to the Earth. The present work is devoted to the study of characteristics of these events. The special attention is paid to the increase of energetic particle flux on October 28, 2003.
Fig. 1 presents the temporal change of cosmic ray neutron and muon intensity in October-November 2003 by data of the Yakutsk array complex and Tixie Bay station. As seen from Fig. 1, the several Forbush-decreases was registered at this period. Note that the value of Forbush-decrease on October 29 is ~ 30% in the neutron component. Such events are unique by their parameters and are registered one time per the solar activity cycle. The shocks responsible for such events are very powerful and complex by their nature. The field intensity in such shocks is ~ 50 nT. Figs. 2-4 give the temporal profiles for three events of solar energetic particle increases by 5-min neutron monitor data at the Yakutsk and Tixie Bay stations. The solar flares with coordinates S 16° E 08°, S 15° W 02° and W 53° S 23° in the same active region 10486 are responsible for these three increases of energetic particles [1]. By neutron monitor data at the Tixie station, the pulsations in the particle intensity with a period of 20-40 min in a maximum of the event are observed on October 28 and 29. The analysis including the data from cosmic ray stations of Russia shows that Tixie Bay and Shmidt Cape stations being on the night side of the Earth during the event of October 28 registered a sharp increase of particle flux of ~ 7% and 19%, respectively. If we take the maximum of X-rays at 1110 UT and the onset of II type radioburst at 1102 UT as the onset of generation of relativistic particles, then the early increase at the Tixie Bay station at 1120 UT and a plane maximum before the arrival of a shock on October 29 for the solar flare with coordinates S 16° E 08° doesn't fit in the anisotropic diffusion model for the particle propagation in the interplanetary magnetic field. For the increase on October 29 and November 2, 2003 the particle propagation from the solar flare is described by the diffusion process. Thus, the increase of particle flux with $E > 1$ GeV on October 28, 2003 is of the greatest interest.

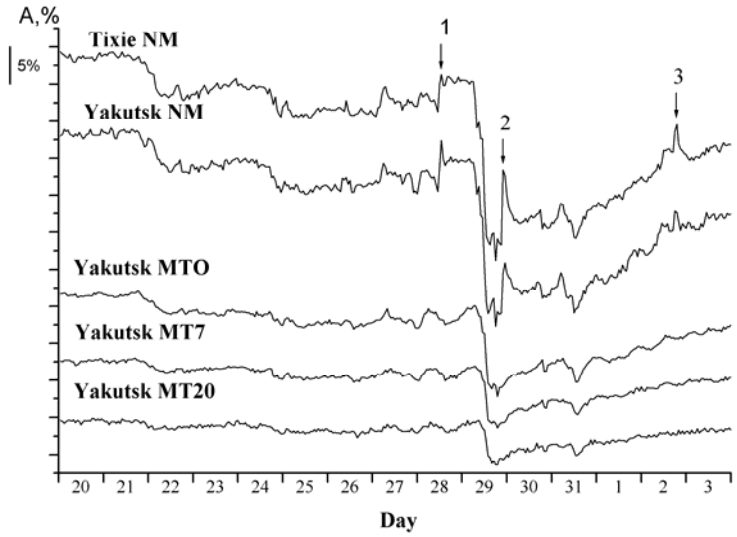


**Figure 1.** Temporal change of the cosmic ray intensity in October-November 2003 by data of the neutron monitors at Tixie Bay and Yakutsk stations, muon 0,7, 20 m w.e. telescopes at the Yakutsk station. The increases of solar energetic particles are marked by arrows and numbers.

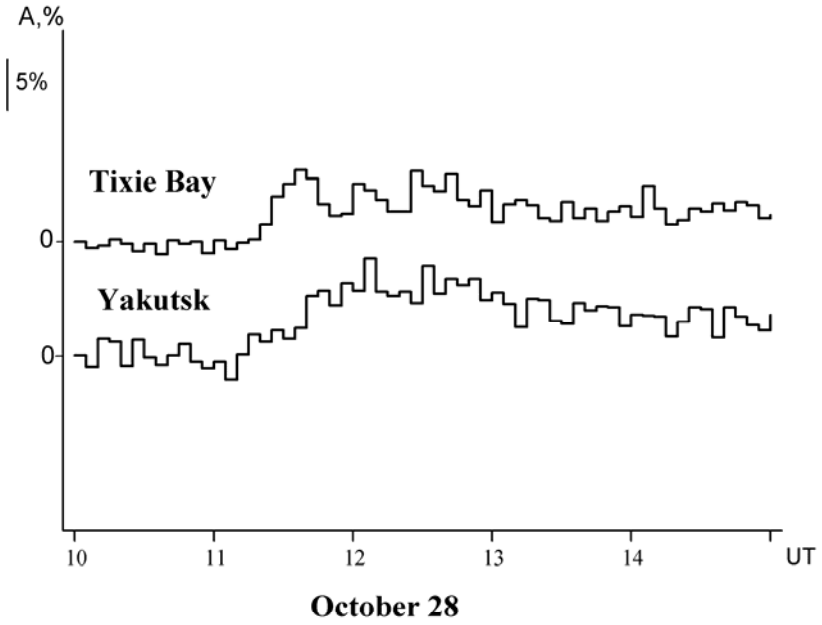


**Figure 2.** Increases of solar energetic particles on October 28, 2003 by 5-min neutron monitor data of the Tixie Bay and Yakutsk stations.

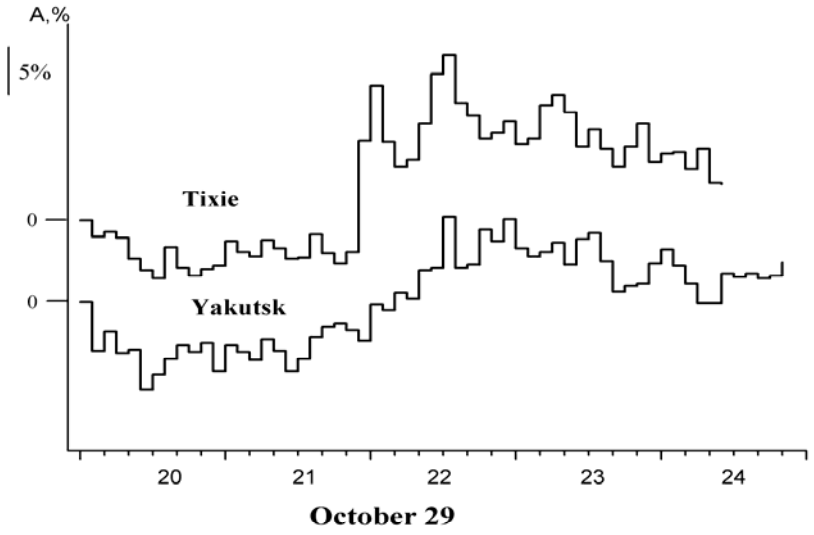


**Figure 3.** Increases of solar energetic particles on October 29, 2003 by 5-min neutron monitor data of the Tixie Bay and Yakutsk stations.

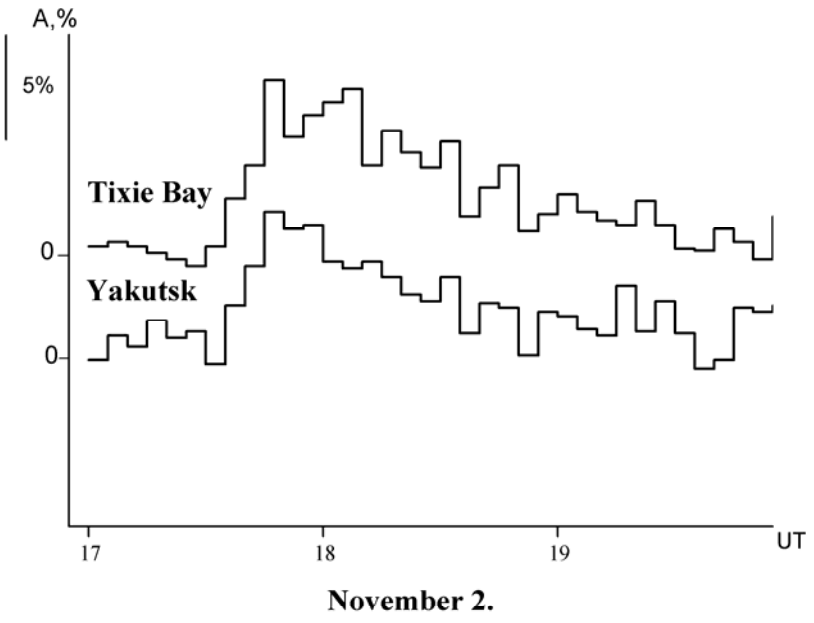


**Figure 4.** Increases of solar energetic particles on November 2, 2003 by 5-min neutron monitor data of the Tixie Bay and Yakutsk stations.

## 2. Discussion

As seen from Fig. 1, during these events the arrival of a few of shocks to the Earth is observed. The shock which came at 0623 UT on October 29 from the flare of October 28 had a velocity ~ 1900 km/s. By Tixie Bay and Yakutsk data the increase of energetic particles with $E > 1$ GeV on October 28 after the achievement of maximum was kept at the high level up to the arrival of a shock on October 29 (Figs. 1 and 2). The estimations showed that velocities of shocks on October 26 and 28 were ~ 1100 km/s and 1800 km/s, respectively [1]. The values of IMF intensity measured reached 60 and 40 nT, respectively [1]. Thus, in these events the subsequent shock had the velocity twice as large as the previous one and the solar energetic particle flux could be "trapped" between two shock fronts drawing together. So, the constant flux of energetic particles with $E > 1$ GeV after the flare maximum and before the arrival of the shock indicates to the fact that the additional flux of particles appears. The analogous phenomenon we observed earlier during the events in June 1959, November 12, 1960, August 4, 1972 and October 12, 1981 [2, 3]. It is shown that these events are caused by the acceleration of particles in the interplanetary medium between shock fronts drawing together [4, 5]. In order to clear up the nature of the additional flux of particles in the event of October 28, 2003 it is necessary to invoke the CR station world network and to carry out the study of the energetic spectrum dynamics of solar energetic particle increases.
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## 3. Conclusions

It is shown that during the event of October 28, 2003 the additional flux of particles with $E > 1$ GeV is observed which is caused by the interaction processes of charged particles with the shock front. In this event instead of the diffusion effect and adiabatic cooling the increase of the particle density is observed.

## 4. Acknowledgements

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