Rigidity dependences of the main characteristics of Forbush decreases

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Introduction. Forbush decreases are short term depressions in the galactic cosmic ray fluxes observed at Earth and interplanetary space. This depressions are caused by coronal mass ejections (CMEs) [1]. CME is a significant release of plasma and accompanying magnetic field from the solar corona, which is often accompanied by Solar Flares. One of such CME is shown on fig. 1. This CME was occurred on 15 of march 2013, and registered by coronagraphs installed onboard Heliospheric Observatory satellite (*SOHO*) .

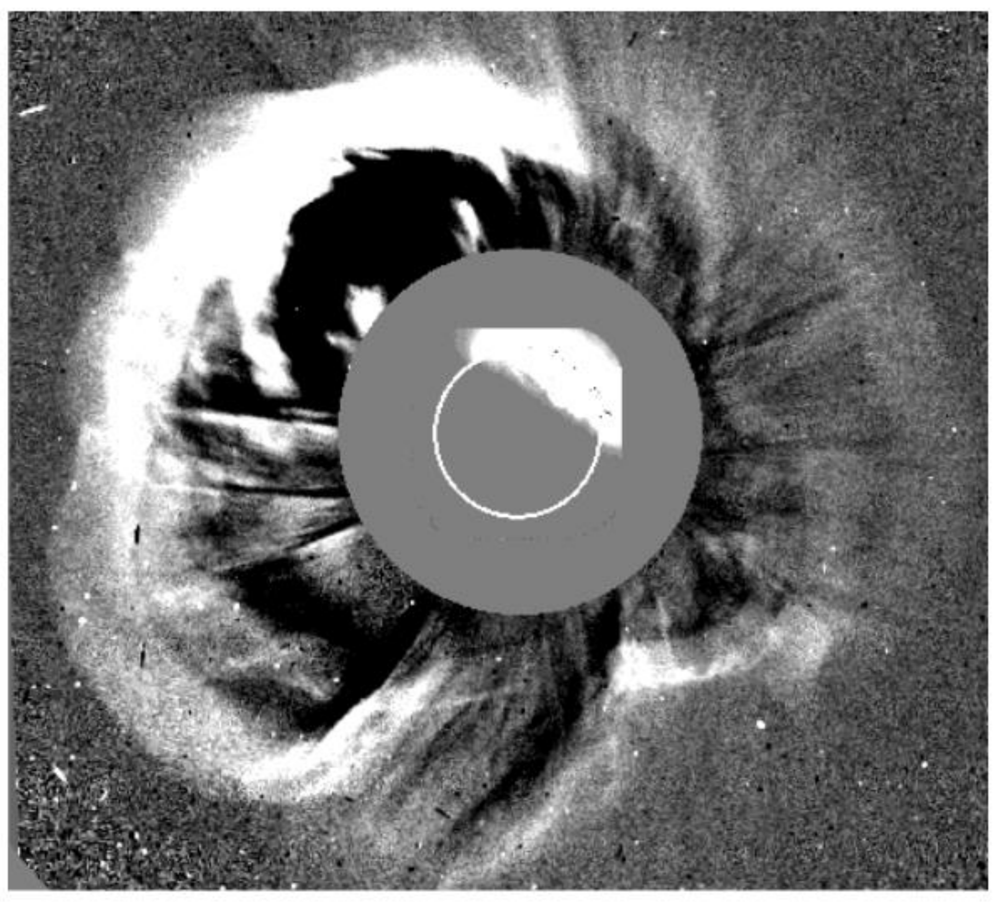

Fig. 1. Halo CME on the Sun (15.03.2013)

CME which propagates outward from the Sun is known as interplanetary coronal mass ejection (ICME) and plays a central role in generating Forbush decrease in the interplanetary space.

Forbush decreases was firstly registered by S. Forbush in 1937 [2]. Despite the fact that FDs have studied more then eighty years, there is no exact theoretical model exist. Nowadays FDs mostly studied by ground based detectors such as neutron monitors and muon horoscopes. This detectors has good statistical capabilities, but register secondary cosmic rays, which is generated by interaction of primary cosmic rays with Earth atmosphere.

In this work we used cosmic ray fluxes obtained by PAMELA experiment. PAMELA is a first satellite-based magnetic spectrometer telescope which was launched on 15 June 2006 attached to the Russian satellite Resurs-DK1. PAMELA was consist of magnetic spectrometer, electro-magnetic calorimeter, time of flight system, anticoincidence systems and neutron detector. FD for the corresponding CME (Fig.1), was registered by PAMELA telescope and shown on Fig. 2. Main properties of interplanetary medium [3] during FD, such as magnitude of magnetic field, solar wind speed, real and expected proton temperature [4] and proton density are also shown on Fig. 2

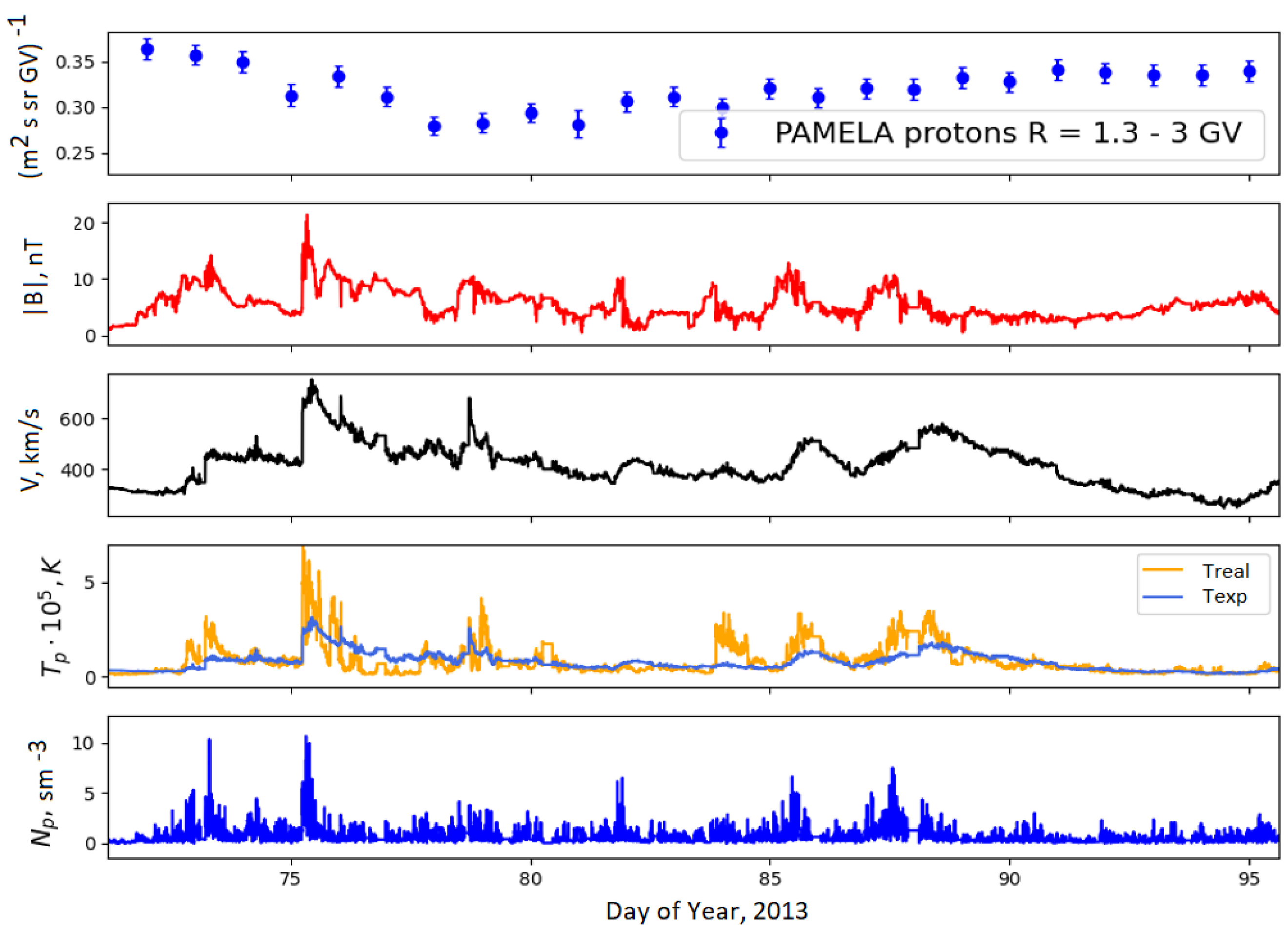

Fig. 2. Forbush decrease in the primary proton flux.

Data analysis. Amplitude and recovery time of Forbush decreases are basic properties of the studied effect. This characteristics describe the main basic part of modulation process of FDs. Some discussions on the rigidity behavior of this basic characteristic are still available in the scientific literature [5,6,7,8]. Also there is no average laws of rigidity dependence of amplitude and recovery time, which were calculated by primary cosmic ray data. In this work we continue to analyze rigidity dependences of this characteristics of selected FD (fig. 2.) which was obtained by PAMELA telescope. On fig. 3. we presented rigidity dependence of amplitude calculated for FD on march 2013, which was created by CME shown on fig. 1.

Obtained $A_{FD}(R)$ curve was fitted by exponential and power laws by least square method.

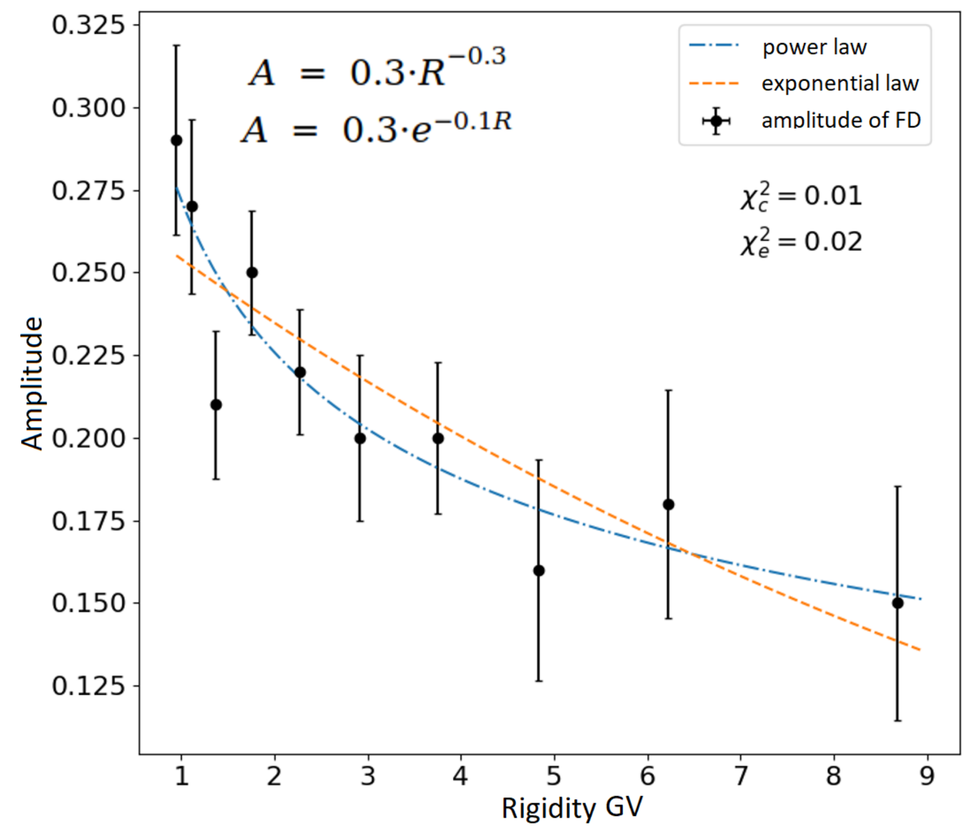

Fig. 3. Rigidity dependencies of amplitudes of FD registered by PAMELA.

Recovery profiles of FD was fitted with the following function:

$$F = F_{av} - A \cdot \exp((t - t_0)/\tau)$$

where Fav – averaged flux of cosmic ray protons before onset of FD. A – amplitude of FD. t0 – start time of FD. τ – recovery time of FD. One of such fitted profiles for the cosmic protons (0.8 GV) with A = 0.3 + 0.1 and τ = 14 + 2, is shown on Fig 4.

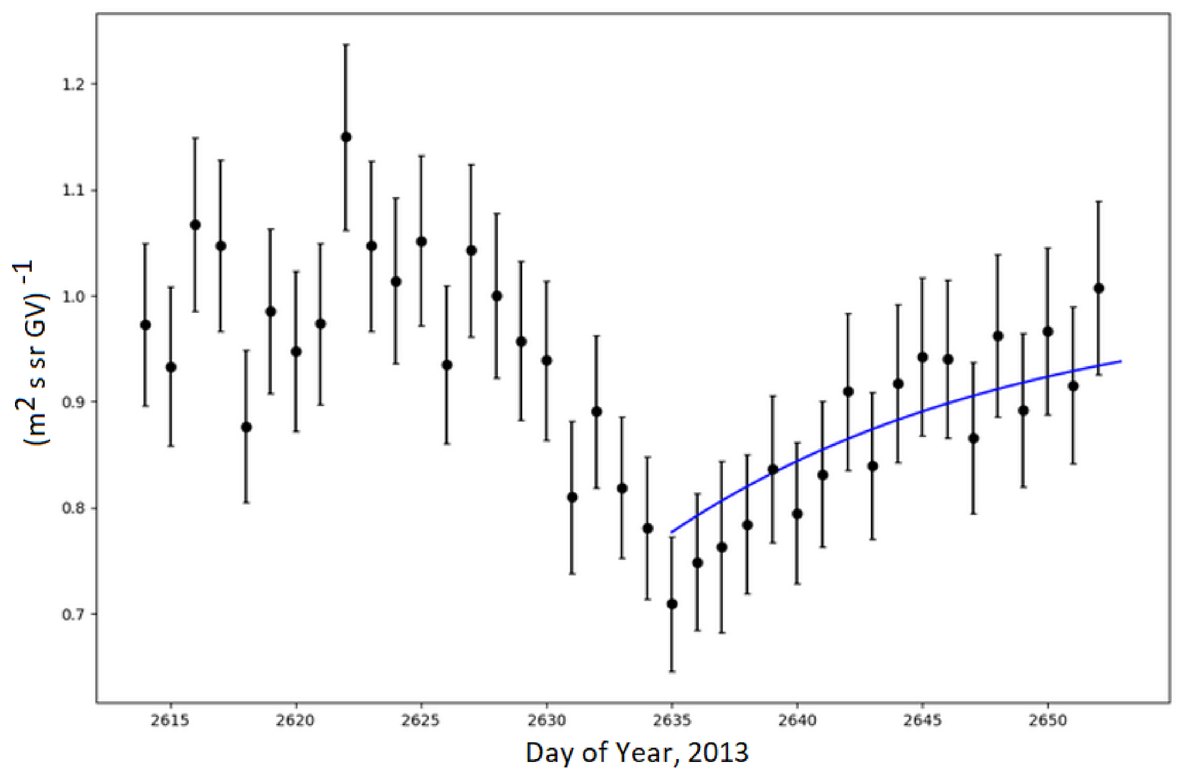

Fig. 4. Fitted recovery profile for FD in 0.8 GV protons.

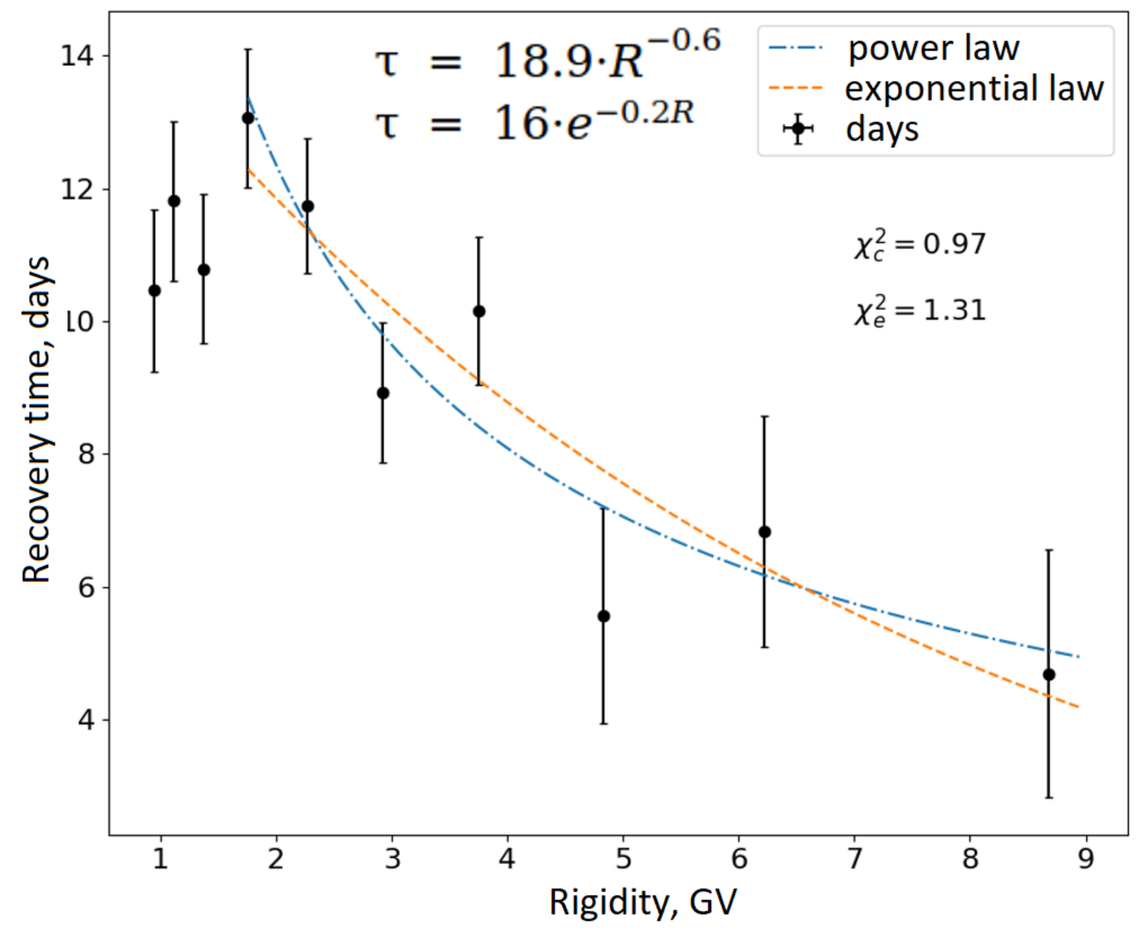

Fig. 4. Rigidity dependencies of recovery times of selected FD registered by PAMELA.

Conslusions. Rigidity dependencies of amplitudes and recovery times of FD which was occurred on march 2013 have been calculated using data on primary cosmic ray protons. This dependencies was fitted by means of power and exponential laws and both of them suggested applicable for that purpose ($\chi_e^2 \sim \chi_p^2$). More FDs would be analyzed which will allow to derive averaged laws of this rigidity dependencies of amplitude and recovery times, which would acceptable for theoretical models.

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