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Investigation of the mechanism of solar flare and acceleration of solar cosmic rays in real conditions of the solar corona

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The generation of solar cosmic rays occurs during explosive energy release in a solar flare, so in order to understand this phenomenon it is necessary to study both the mechanism of the solar flare and the process of particle acceleration by the generated electric field. It is necessary to investigate the processes of explosive release of energy and acceleration of charged particles occurring in the solar corona for really occurred flares. During a solar flare in the solar corona above the active region (AR), the energy stored in the magnetic field of the current sheet is released. The current sheet is formed in the vicinity of a singular X-type line in the magnetic field of the solar corona as a result of the accumulation of disturbances propagating from the solar surface. Numerical magnetohydrodynamic (MHD) simulation in the corona, when all conditions are taken from observations and no assumptions about the flare mechanism are done in advance, confirmed the current sheet mechanism. Using the results of numerical simulation and observations, I.M. Podgorny proposed an electrodynamic model of a solar flare, explaining its main observational manifestations, in particular, the appearance of X-ray emission on the surface of the Sun. The acceleration of protons occurs along a singular line of the magnetic field of the current sheet by the electric field $\mathbf{E} = -\mathbf{V} \times \mathbf{B}/c$, which increases during the instability of the current sheet. This mechanism of solar cosmic rays generation is confirmed by comparing the spectrum found by calculating the proton trajectories in the electric and magnetic fields obtained by MHD modeling with the spectrum obtained from the data of the worldwide network of neutron monitors. In order to get rid of the instability distorting the numerical solution caused by the unnaturally rapid change in the magnetic field at the photospheric boundary with the previously performed MHD simulation in the in the reduced scale of time, it is necessary to carry out MHD simulation in the real scale of time. Also, such a simulation is necessary for a more accurate study of the acceleration of charged particles and the possibility of their exit from the region of a strong magnetic field by calculating the particle trajectories in the electric and magnetic fields obtained by MHD simulation. MHD simulation in the solar corona above AR in the real scale of time can only be done using parallel computing on a supercomputer. The parallelization of the program PERESVET for numerical solving MHD equations of in two ways was carried out. Parallel computing with an OpenMP system uses many computer processor (CPU) threads. The most effective parallel computations were carried out using CUDA technology using graphics card (GPU) processors specially adapted for parallel computations. After a series of optimizations of the data exchange processes between the GPU memory and the memory of the CPU, the calculations for numerical solution of the MHD equations were accelerated by ˜ 40-50 times. As a result of optimization of the approximation of the boundary conditions of free exit at the non-photospheric boundary, at which the plasma velocity near the boundary is significantly reduced, instability near the boundary, which previously hindered the numerical solution, was stabilized. The first results of MHD simulation in the real scale of time above the AR 10365 showed the appearance of a plasma flow near singular X-type lines, which have to cause to the formation of a current sheet. MHD simulation in the corona above the AR 10365 in the real scale of time and further optimization of the parallel computing method using CUDA technology for the numerical solution of MHD equations continues.

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