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Self-consistent simulations of proton acceleration at coronal shock

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Acceleration of solar energetic particles (SEPs) is one of the key problems in which modern and future space missions are expected to give substantial progress. The data obtained can be used to improve theoretical models of the acceleration processes. A suitable approach in this, especially in the case of shock-accelerated SEPs, is Monte Carlo simulations. Being based on consideration of individual particles interacting with turbulence, Monte Carlo simulation models can provide detailed information on particle and turbulence distributions in the vicinity of the shock. However, the existing Monte Carlo models, relying on the quasi-linear approximation for interactions of particles with Alfvénic turbulence, often use a simplified way (neglect the pitch-angle dependence in the resonance conditions) to model the interactions.

In this presentation, we will focus on two aspects of the shock acceleration process: self-consistent modelling of particle acceleration and foreshock turbulence in coronal shock fronts and stochastic re-acceleration of energetic (shock-accelerated) protons by shock-amplified self-consistently damped Alfvénic turbulence in the shock's downstream region. While the first process typically results in steep, super-exponentially cut-off energy spectrum of protons, spectral form resulting from the second process is a double power-law, where the spectral index of the high-energy tail is determined by the ratio of the energy density of shock-accelerated protons to the Alfvén wave energy density in the shock's downstream region. We compare the results of shock-accelerated particle spectrum and foreshock turbulence with results obtained from earlier Monte Carlo models (where the resonance condition between the particles and the waves has not been modeled in full) and show that while the spectra are qualitatively similar in both cases, quantitative differences in the acceleration efficiency of the models exist.