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Particle acceleration in coronal and interplanetary shocks: quasilinear and hybrid-Vlasov simulations

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We present a study of particle acceleration at travelling coronal / interplanetary shocks. We use three simulation codes for the purpose: (1) the global CSA Monte Carlo simulation code; (2) the local SOLPACS Monte Carlo simulation code, and (3) the Vlasiator hybrid-Vlasov code, initially developed for global magnetospheric simulations, but used here for local simulations of interplanetary shocks. CSA and SOLPACS solve the evolution of the coupled system of energetic particles and Alfvénic turbulence upstream of a shock, using the quasilinear approximation in the description of wave-particle interactions. CSA simplifies the resonance conditions between the particles and the waves, whereas SOLPACS uses the full quasilinear description of the interaction. They compute the intensity of accelerated particles and the power spectrum of resonant Alfvén waves on a single magnetic field line connected to the shock. The advantage of this statistical approach is that large spatial domains can be covered without extensive computational demand, as the wave length of the resonant fluctuations is not resolved by the simulation. However, in this approximation no information on the wave phases can be obtained. Vlasiator, on the other hand, resolves the ion scale fluctuations in front of the shock in full. This allows investigations of wave forms in the foreshock, but limits the extent of the computational domain possible with present computational resources. Furthermore, the Monte Carlo codes use the gyrotropy assumption, whereas Vlasiator solves the 3D velocity distributions in full.

Our study is focused in the comparison of the simulation results with each other to reveal the range of validity of the codes in terms of energy spectra and spatial distributions of particles and the power spectra of waves in the foreshock region. We will discuss the implications of the results to shock acceleration in the solar corona and interplanetary medium and the possibilities to move towards operational models forecasting the evolution of large gradual SEP events.

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