Ion acceleration around shocks using multi-physics simulation model

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We have developed a new type of simulation technique by directly interlocking a traditional Ion-Particle Hybrid simulation model (Hybrid) and an Energetic-Particle Hybrid simulation (EP-HYB) model. In the traditional Hybrid model, all ions are kinetically treated as particles. In the EP-HYB model, non-thermal energetic ions are kinetically treated, and the thermal component is calculated as a fluid. The interlocked model is applied to a two-dimensional collisionless shock problem. The domain for the Hybrid model is embedded in a part of the system, and the bounded data are exchanged to each other to keep the consistency between both models. It can handle the full ion kinetics to investigate the injection problem at the shock transition region, as well as the wave-particle interactions in even far upstream region in EP-HYB area. We have carried out the long-term simulation of the shock acceleration process using this interlocked model, and successfully reproduced the power-law distribution function with high energy cut-off, that is characteristic energy (Ec). The power-law index is almost constant in time, on the other hand, the characteristic energy increases in time, resultantly high energy particles are observed. Since the calculation cost of the EP-HYB model is much smaller than that of the Hybrid model, we can considerably reduce the computational demand.