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Hybrid kinetic models of shocks in astrophysical and laboratory plasmas: PIC vs CPK vs CPK/FMM(SFK) concepts

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Many macroscopic problems in plasma physics are characterized by ion Larmor radii comparable to the scale lengths of the system. For these problems, and for problems involving micro-instabilities, a fluid description of the ions is inadequate, and the ions must instead be treated in a fully kinetic manner. The phenomena in the astrophysical and laboratory plasmas present a various wave-particle interaction which is responsible for electrostatic and electromagnetic instabilities and particle heating and acceleration. The most of these effects are controlled by the non-Maxwellian particle velocity distributions and finite gyroradius. These effects are major features in the formation of the fine structure of the collision less shocks, the reconnection in plasma systems with reversed magnetic configuration, and plasma beams. Note such phenomena cannot be self-consistently studied using MHD/multi-fluid/Hall-MHD models. In this talk, we shall discuss the current status of the hybrid computational models: standard particle-in-cell (PIC), complex particle kinetic approach (CPK), and the combination of complex particle kinetic approach (CPK) and finite mass method (FMM)- shape function kinetics method (SFK). The CPK method includes the internal dynamics of the probe Maxwellian distributions (time-dependent shape functions in phase space) and fragmentation of macro-particles to probe for emerging features and refined merging where fine macro-particles are no longer needed. In opposite to CPK, the CPK/FMM uses the re-mapping(re-starting) for particle distribution to get fine structures in phase space. Both CPK and CPK/FMM algorithms need much smaller computational resources in comparison with a standard CPK method. We shall also discuss the results of modeling for a study of the shock dynamics and particle acceleration, astrophysical explosion, and non-linear field line resonance triggered by shocks.

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