DSMC Methods For Multi Component Plasmas

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Kinetic treatment of plasma systems plays an important role in a description of macroscopic plasma properties that cannot be learned under hydrodynamic approach. Numerical simulation of plasma dynamics on the kinetic level is a difficult problem for several reasons, particularly because of its spatial-temporal multiscaling. It is natural to consider separately (a) continuous motion of electrons and ions in external and self-consistent electro-magnetic fields (Vlasov-Maxwell kinetic equations) and (b) Coulomb collisions (Landau-Fokker-Planck equations). The particle methods for solving the first stage (a) of a "collisionless" plasma are very well developed and discussed in literature. To model collisions of charged particles Monte Carlo methods are usually used for operating linear problems. This is because such an approach faces severe difficulties for the interaction potentials of the infinite radius of action for the nonlinear kinetic equations. We propose a general approach to stochastic methods (DSMC) for Coulomb collisions. Its key idea is an approximation of the nonlinear Landau-Fokker-Planck equations by the Boltzmann equations of a quasi-Maxwellian kind. This means that the total collision frequency for the corresponding Boltzmann equation does not depend on velocities. This allows one to make the simulation process very simple since the collision pairs may be chosen arbitrarily, without restriction. The suggested new numerical scheme is simple, effective and easily may be combined with the particle methods. We derive it for the general case of multi component plasmas. DSMC numerical simulation is tested for the classical problems of plasma physics and nuclear fusion: runaway electrons, two-temperature relaxation, plasma dynamics in the external high-frequency weak electrical field, etc. The developed method can be also applied not only to Coulomb potential but to other long-range potentials such as dipole-dipole interactions, van der Waals attractions between atoms, etc.

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