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Multi-Moment Advection (MMA) Scheme for Vlasov Simulations

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We present a new method for solving the advection equation, and its application to Vlasov simulations. The numerical method for solving the Vlasov equation is still developing. Various high-accuracy schemes for the Vlasov simulation have been proposed so far (cf., Filbet et al. 2003, CPC). With those schemes, however, it is still difficult to discuss plasma kinetics due to their insufficient accuracy. Especially, a significant numerical diffusion in the velocity space makes it difficult to discuss plasma heating and acceleration processes. Our aim is to develop an extremely less-diffusive scheme for the Vlasov simulation.
The numerical diffusion causes an unexpected increase of the information entropy of a profile. Since the entropy can be described as a linear combination of the n-th order momentum, it is essential for diminishing the numerical diffusion to guarantee conservations of all momenta. For example, Yabe et al. (2001, Mon. Wea. Rev.) have proposed the CIP-CSL2 scheme which guarantees the zeroth order momentum (corresponding to the mass).
Based on this idea, we propose a new scheme that independently possesses and solves piecewise values of the zeroth, first, and second order momenta as well as the profile, called "Multi-Moment Advection (MMA)" scheme. We have successfully developed the one- and two-dimensional schemes (MMA1D, MMA2D). MMA2D can properly solve the solid rotation problem (for more than hundred times rotation) within a reasonable memory usage compared to other existing schemes, which is critically important for the electromagnetic Vlasov simulations. In this talk, we show details of the MMA scheme and its application to the electrostatic and electromagnetic Vlasov simulations.

Keywords: Vlasov simulation