Vlasov and drift kinetic simulation methods based on the symplectic integrator

Tomo-Hiko Watanabe[1]

[1] NIFS

Numerical simulations for the Vlasov and/or drift (gyro-) kinetic equations based on advanced computer technologies have provided a considerable amount of information which is useful for comprehension of kinetic plasma behaviors with strong nonlinearity, and have applied to a wide variety of problems in researches on fusion, space, and astrophysical plasmas. Simulation methods for solving the Vlasov-Poisson equations have been extensively developed since 1970's to study nonlinear kinetic phenomena in electrostatic plasmas. The splitting scheme proposed by Cheng and Knorr [1] is widely used, where the Vlasov equation is integrated in time by means of the successive coordinate transformations of the distribution function f in the x and v spaces. Recently, we have considered generalization of the splitting scheme which is based on the symplectic integrators [2,3].

By noting that the coordinate transformation in the second-order splitting scheme is nothing but a mapping of f generated by the leap-frog integrator, we can construct a higher-order time-integration scheme by means of the explicit symplectic integrator for the separable Hamiltonian system, H(q,p)=T(p)+V(q). It is confirmed that the Nth-order scheme improves the total energy conservation as Dt^N where Dt is a time step size [3]. Conservation properties of the other invariants such as the entropy and the L^1 and L^2 norms are also rigorously benchmarked.

It is known that an implicit symplectic method is applicable to a non-separable Hamiltonian system such as the drift particles. Then, an Eulerian drift kinetic simulation scheme is derived from a mapping of f generated by the implicit symplectic integrator [2,3], where the time-reversibility of the basic equation is preserved. It is also an advantage of this scheme that conservation of the L^2 norm is automatically guaranteed. The newly developed code is benchmarked for a test problem of the Kelvin-Helmholtz instability [3], and results in successful application to the turbulent transport caused by the ion temperature gradient instability where the entropy balance in the system is definitely confirmed [4].

[1] C.Z.Cheng and G.Knorr, J.Comput.Phys. 22, 330 (1976).
[2] T.-H.Watanabe, H.Sugama, and T.Sato, J.Phys.Soc.Jpn 70, 3565 (2001).
[3] T.-H.Watanabe, and H.Sugama, submitted to Transp.Theo.Stat.Phys.
[4] T.-H.Watanabe and H.Sugama, Phys.Plasmas 9, 3659 (2002).

Remarks: This is a collaboration work with Dr.H.Sugama (NIFS).