磁気リコネクションの２次元ブラソフシミュレーション

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Two-dimensional Vlasov code simulation of magnetic reconnection

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There are numerous types of self-consistent simulations that treat plasmas according to some approximations. The fluid codes are used to study global and macroscopic processes in space plasmas. Nonlinear microscopic processes in space plasmas are studied with kinetic simulation codes. Numerical methods for kinetic simulations fall into two groups. One is particle-in-cell (PIC) method which follows motions of individual particles in a self-consistent electromagnetic field. However, a limitation on the number of particles gives rise to numerical thermal fluctuations. Another approach is Vlasov method which follows spatial and temporal development of distribution functions in the position-velocity phase space. In contrast to PIC codes, numerical noise is substantially suppressed. However, Vlasov codes require huge computer resources to represent distribution functions and Vlasov simulation techniques are still developing. Owing to the rapid advancement of recent computer technology, Vlasov code simulation would be more essential in the near future.

In the present study, a new two-and-half-dimensional and fully electromagnetic Vlasov simulation code is developed in which phase-space distribution functions are defined in five-dimensional position-velocity phase space(x,y,vx,vy,vz). The Vlasov equation in two-dimensional configuration and three-dimensional velocity spaces is solved with a non-oscillatory and conservative scheme, and the full set of Maxwell's equations are self-consistently solved based on the implicit Finite Difference Time Domain (FDTD) method.

The Geospace Environment Modeling (GEM) magnetic reconnection challenge is chosen as a benchmark test of our two-dimensional Vlasov code. The result is compared with the past simulation results with Darwin-Vlasov, explicit PIC and implicit PIC codes. The present simulation with a very-low spatial resolution gives a high growth rate of magnetic flux, which is in agreement with the results of the GEM reconnection challenge.