Conservative Semi-Lagrangian Vlasov solvers on mapped meshes*

M. Mehrenberger, M. Bergot, H. Sellama, E. Sonnendrücker
IRMA, UDS et CNRS, 7 rue René Descartes
67084 Strasbourg, FRANCE

V. Grandgirard, G. Latu
CEA/IRFM, 13108 St Paul les Durance, FRANCE

We are interested in the numerical solution of the collisionless kinetic or gyrokinetic equations of Vlasov type needed for example for many problems in plasma physics. Different numerical methods are classically used, the most used is the Particle In Cell method, but Eulerian and Semi-Lagrangian (SL) methods that use a grid of phase space are also very interesting for some applications. Rather than using a uniform mesh of phase space which is mostly done, the structure of the solution, as a large variation of the gradients on different parts of phase space or a strong anisotropy of the solution, can sometimes be such that it is more interesting to use a more complex mesh. This is the case in particular for gyrokinetic simulations for magnetic fusion applications. We develop here a generalization of the Semi-Lagrangian method on mapped meshes. Classical Backward Semi-Lagrangian methods (BSL), Conservative Semi-Lagrangian methods based on one-dimensional splitting or Forward Semi-Lagrangian methods (FSL) have to be revisited in this case of mapped meshes. A first use of the classical advective BSL method on a mapped mesh has been described in [1]. We consider here the problematic of conserving exactly some equilibrium of the distribution function, by using an adapted mapped mesh, which fits on the isolines of the Hamiltonian. This could be useful in particular for Tokamak simulations where instabilities around some equilibrium are investigated. We also consider the problem of mass conservation. In the cartesian framework, the FSL method automatically conserves the mass, as the advective and conservative form are shown to be equivalent. This does not remain true in the general curvilinear case. Numerical results are given on some gyrokinetic simulations performed with the GYSELA code and show the benefit of using a mass conservative scheme like the conservative version of the FSL scheme.

1. J. Abiteboul, G. Latu, V. Grandgirard, A. Ratnani, E. Sonnendrücker, A. Strugarek, Solving the Vlasov equation in complex geometries, ESAIM: Proceedings (2011).

* Work supported by ANR Project GYPSI