Recent Advances for Nonlinear PIC Simulations in Magnetic Coordinates

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Nonlinear Particle-In-Cell (PIC) simulations are a useful tool for studying ITG modes, which are commonly held responsible for the turbulence observed in tokamaks. However, this method unavoidably gives rise to numerical noise and leads further to the loss of energy conservation in the saturation phase.

In the nonlinear gyrokinetic code ORB5 [1], the particle orbits are solved in cylindrical coordinates (r,z,φ), whereas charge assignement and Poisson equation are computed on a (s,θ,φ) grid. Therefore, at each time step and for each marker, the transformation (r,z)→ (s,θ) is performed using linear interpolations, making the whole simulation less accurate.

This work presents the implementation of a new nonlinear gyrokinetic model in ORB5 which completeley avoids interpolations between 2 different grids during the simulation. A new set of coordinates ($\xi = s\cos\theta_*$, $\eta = s\sin\theta_*$) is used for the guiding center trajectories to avoid the singularity at the magnetic axis, θ_* being the straight-field-line angle and $s = \sqrt{(\psi/\psi_{edge})}$ the radial coordinate. The Poisson equation is solved on a (s,θ_*) grid. This model has been successfully applied to the linear version (LORB5) of ORB5 for circular equilibria, and described in a previous publication [2]. Here we describe its implementation in the nonlinear code ORB5.

Moreover, ITG modes tend to align along the field lines, thus we can take advantage of the straight-field-line coordinate. By comparing simulations with the old and the new gyrokinetic schemes, we point out the advantages of using magnetic coordinates.

References

[1] T. M. Tran *et al*.., Theory of Fusion Plasmas, Int. Workshop (page 45), Editrice Compositori, Societa italiana di Fisica, Bologna, 1999

[2] S. Jolliet et *al.*, Theory of Fusion Plasmas, Int. Workshop (page 345), Editrice Compositori, Societa italiana di Fisica, Bologna, 2005