A gyro-kinetic model for trapped electron and ion modes

T. Drouot[1], E. Gravier[1], T. Reveille[1], A. Ghizzo[1], P. Bertrand[1],
X. Garbet[2], Y. Sarazin[2], P. Ghendrih[2], V. Grandgirard[2]

[1] IJL, UMR 7198 CNRS - Université de Lorraine,
54 500 VANDOEUVRE-LES-NANCY, France.
[2] CEA, IRFM, F-13108 Saint-Paul-Lez-Durance cedex, France.

The understanding of the transport in tokamak plasma is an important step in order to perform the nuclear fusion. It is well known that the particle and energy transport is dominated not by Coulomb collisions but by turbulence especially in the core plasma. It is recognized that ITG (ion temperature gradient instability) and trapped electrons mode (TEM) are held responsible for turbulence giving rise to anomalous transport [1] [2] [3]. The present work focuses on the trapped ion and electron modes (TIM and TEM)[1] [2] [3].

First of all, we remark that the motion of trapped particles in tokamak is integrable and it can be divided into three parts: the cyclotron motion which consists of a fast rotation around the magnetic field lines, a "banana" like shape poloidal motion and a toroidal precession. Thus, in agreement with classical mechanics, it is interesting to use a set of action-angle variables where angles are related to these frequencies and actions are three invariants related to the magnetic moment μ, the energy E and the toroidal kinetic momentum M. In this framework the Hamiltonian at the equilibrium depends only of actions so that using these coordinates provides great simplifications.

In addition, we reduce the dimentionality by averaging the motion over the cyclotron motion and the "banana" orbits, according to the fact that the instabilities are characterized by frequencies of the order of the low trapped particle precession frequency. The final model is 2D, parametrized by the two first adiabatic invariants namely the particle energy and the trapping parameter. Vlasov equations are much easier to solve using such a model.

The main difficulty of the model is the quasi-neutrality constraint which ensures the self-consistency of the model. In this set of variables, the velocity no longer appears explicitly, and the density of particles, which is the integral of the distribution function over velocity, is more difficult to obtain. Nevertheless, an integration is nothing but a sum thereby quasi-neutrality constraint is numerically easier to solve than a differential Vlasov equation. Furthermore, the model discussed in this paper also takes into account a linear response of passing particles, as well as a multi ion species plasma.

This work is currently performed in order to include trapped electrons in an existing semi lagrangian code for which TIM modes are already taken into account. This study can be considered as a first step in order to include kinetic trapped electrons in the 5D gyrokinetic code GYSELA.

References

[1] G. Depret *et* al. , *Plasma Phys. Control. Fusion*, **42**, 949 (2000)

[2] Y. Sarazin *et* al. , *Plasma Phys. Control. Fusion*, **47**, 1817 (2005)

[3] A. Ghizzo *et* al. , *Phys. Plasmas*, **17**, 092501 (2010)