Multi Water Bag modelling of drift kinetic electrons and ions plasmas

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A serious difficulty in the modelling of the instabilities and the turbulence in plasmas lies in the large mass ratio between ions and electrons. Consequently, a complete description of a plasma requires a large amount of space and time scales to describe ion dynamics as well as electrons dynamics, that can make very expensive the simulation costs [1,2]. A widely used hypothesis to circumvent this problem consists in assuming adiabatic electrons, where electron inertia is set to zero due to their mass smallness. But this approach neglects electron scale physics that can play an important role, for instance by leading to a residual heat transport in the case of the micro-turbulence in magnetic fusion plasmas [3].

In order to describe strongly magnetized plasmas, the Vlasov Maxwell system can be reduced to the gyrokinetic equations, where the fast cyclotron gyration is filtered out so that the gyrokinetic phase space reduces to three space coordinates and only one velocity coordinate, namely the velocity parallel to the magnetic field [4]. A fundamental property of the Vlasov equation, inherited from Liouville's theorem, and shared with the gyrokinetic Vlasov equation, is to conserve the phase space volume. Based on this conservation, the Water Bag Model consists in choosing a special class of distribution function, taking a multi-step-like form along the parallel velocity coordinate. This choice allows to reformulate the gyrokinetic equations into a set of incompressible multi-fluids equations, with an exact closure [5].

We consider here the "drift kinetic" limit of the gyrokinetic equations, where the strong magnetic field strength allows to assume that particles are located on their guiding centers. A cylindrical plasma column will be considered, as a limit of an infinite aspect ratio tokamak. The simple case of a multi-water-bag electron distribution function with adiabatic ions is first considered. The linear stability analysis of a multi-water-bag electron distribution function with adiabatic ions is compared to the opposite case of a multi-water-bag ion distribution function with adiabatic electrons. The effect of taking into account multi-water-bag distribution functions both for ions and electrons is analysed into details.

References

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