Gyrofluid and gyrokinetic approaches for the study of the collisionless plasmoid instability

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Non-collisional current sheets that form due to the nonlinear development of the tearing instability are characterized by a very small thickness, of the order of the electron skin depth. They can break up into plasmoids (bottom panel of Fig. 1) and make it possible to achieve high reconnection rates. In strike contrast with the body of work that has investigated the marginal stability of reconnecting current sheets where reconnection is driven by plasma resistivity, no work has so far investigated the marginal stability conditions for the development of plasmoids when the forming current sheet is purely collisionless, even though magnetic reconnection in nature is often driven by collisionless effects beyond the resistive MHD description of the plasma.

We investigated the plasmoid formation employing fluid, gyrofluid and gyrokinetic simulations, assuming a plasma with cold ions that is immersed in a strong guide field, resulting in small plasma β_e, where β_e is the ratio between the kinetic pressure of the electrons and the magnetic pressure. The gyrofluid model is a two-field model that retains electron inertia, electron finite Larmor radius effects and perturbation of the guide field [1], while the adopted gyrokinetic model is a δf model, from which the fluid model can be derived with appropriate approximations and closure hypotheses. The gyrokinetic equations are solved by means of the Astro GK code, used in [2].

By comparing the fluid/gyrofluid and the gyrokinetic simulations of reconnection triggered by collisionless effects, we analyzed the geometry that characterizes the current sheet, and what promotes its elongation. Once the current sheet is formed, it is then possible to identify the regimes for which it is plasmoid unstable. This study shows that plasmoids can be obtained, in this context, from current sheets with an aspect ratio smaller than what was anticipated so far in the resistive regime. The study makes it possible to investigate the effect of a finite, although small, β_e on the plasmoid instability. This project also aims to study the impact of the closure applied on the moments, performed during the derivation of the gyrofluid model, on the distribution and conversion of energy during reconnection.

References

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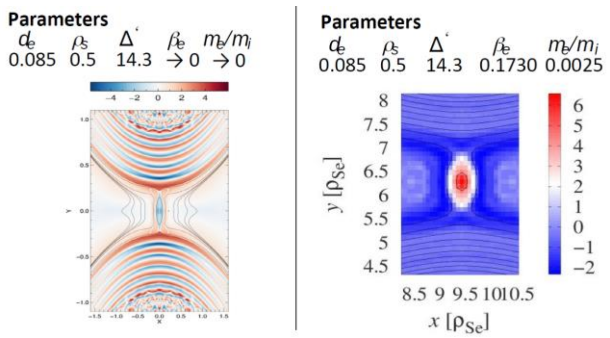

Figure 1. Left panels: fluid simulations. Right panels: gyrokinetic simulations with the same electron skin depth d_e and sonic Larmor radius ρ_s. For the fluid case, we show the contour of the parallel electron velocity. For the gyrokinetic case, we show the contour of the current density.