A gyrokinetic moment-based method to simulate the turbulent plasma dynamics in the boundary of fusion devices

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Understanding the turbulent dynamics of the plasma in the boundary of fusion devices - the region close to the material walls, which includes the edge, the external part of the closed flux surface region, and the scrape-off layer, where the magnetic field lines intercept the machine vessel - is of crucial importance on the way to fusion energy and a critical issue to make reliable predictions of the performances of future experiments, such as ITER. Analytical progress and numerical simulations of the plasma boundary is made particularly challenging because of the multiscale and multiphysics nature of this region, large-amplitude fluctuations, large deviations from thermal equilibrium, and a wide range of plasma parameters that lead to broad differences of plasma collisionality. Therefore, while gyrokinetic simulations are successfully applied to determine the turbulent plasma dynamics in the collisionless regime of the core and fluid simulations are used to study the dynamics of collisional plasmas of the scrape-off layer, it is challenging to represent both regions at the same time.

Bridging the gap between gyrokinetic and fluid simulations in this presentation, a novel moment-based method is described to approach the simulation of the plasma boundary. In particular, a suitable pseudo-spectral decomposition in velocity-space for the particle distribution allows us to develop the gyrokinetic Boltzmann equation onto a set of fluid-like equations that retain collisional effects described by the full gyrokinetic Coulomb collision operator [1,2]. The method we present offers a numerical framework capable of going beyond the fluid limits and recovering the kinetic results of gyrokinetic models over a wide range of plasma parameters [3]. The first implementation of a linearized gyrokinetic Coulomb collision operator using the moment approach and comparisons with the GENE code are presented and discussed. In particular, we show the numerical efficiency of the moment approach as the collisionality increases, a desired property for boundary plasma applications.

[1] Frei B. J., Jorge R. and Ricci P. 2020 A gyrokinetic model of the plasma periphery of tokamak devices. *J. Plasma Physics* **82** (2), 905860205

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[3] Frei B. J., Ball. J., Hoffmann A., Jorge R., Ricci P. and Stenger L. Development of advanced linearized gyrokinetic collision operators using a moment approach. *Submitted to J. Plasma Physics.*