**Title:** A moment-based model for plasma dynamics at arbitrary collisionality

Abstract

Despite significant development over the last decades, a model able to describe the periphery region of magnetic confinement fusion devices, extending from the edge to the far scrape-off layer, is still missing. This is because this region is characterized by the presence of turbulent fluctuations at scales ranging from the Larmor radius to the size of the machine, the presence of strong flows, comparable amplitudes of background and fluctuating components, and a large range of collisionality regimes. The lack of a proper model has undermined our ability to properly simulate the plasma dynamics in this region, which is necessary to predict the heat flux to the vessel wall of future fusion devices, the L-H transition, and ELM dynamics. These are some of the most important issues on the way to a fusion reactor. In the present thesis, a drift-kinetic and a gyrokinetic model able to describe the plasma dynamics in the tokamak periphery are developed, which take into account electrostatic fluctuations at all relevant scales, allowing for comparable amplitudes of background and fluctuating components. In addition, the models implement a full Coulomb collision operator, and are therefore valid at arbitrary collisionality regimes. For an efficient numerical implementation of the models, the resulting kinetic equations are projected onto a Hermite-Laguerre velocity-space polynomial basis, obtaining a moment-hierarchy. The treatment of arbitrary collisionalities is performed by expressing the full Coulomb collision operator in guiding-center and gyrocentre coordinates, and by providing a closed formula for its gyroaverage in terms of the moments of the plasma distribution function, therefore filling a long standing gap in the literature. The use of systematic closures to truncate the moment-hierarchy equation, such as the semi-collisional closure, allows for the straightforward adjustment of the kinetic physics content of the model. In the electrostatic high collisionality regime, our models are therefore reduced to an improved set of drift-reduced Braginskii equations, which are widely used in scrape-off layer simulations. The first numerical studies based on our models are carried out, shedding light on the interplay between collisional, using the Coulomb collision operator, and collisionless mechanisms. In particular, the dynamics of electron-plasma waves and the drift-wave instability are studied at arbitrary collisionality. A comparison is made with the collisionless limit and simplified collision operators used in state-of-the-art simulation codes, where large deviations in the growth rates and eigenmode spectra are found, especially at the levels of collisionality relevant for present and future magnetic confinement fusion devices.

Key-words: Plasma Physics, Nuclear Fusion, Magnetic Confinement, Plasma Turbulence, Plasma Instabilities