An analytical model for scrape-off layer plasma dynamics at arbitrary collisionality

R. Jorge[1,2], P. Ricci[1], and N. F. Loureiro[3]

[1]École Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland
[2]Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal
[3]Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

The lack of an appropriate model to describe the plasma dynamics in the tokamak scrape-off layer (SOL) has undermined our ability to reliably predict the heat flux to the vessel wall of future fusion devices, one of the most important issues on the way to fusion energy. Because of large fluctuations, the plasma properties in the SOL vary significantly, resulting in an extremely large range of collisionality values. Commonly used SOL descriptions are based on a fluid Braginskii-like description, which is valid only at high collisionalities; gyrofluid and gyrokinetic SOL models are also used, but these rely on linearised collision operators, which cannot be justified for the SOL, where deviations from a thermal distribution function might be large.

We have recently developed a drift-kinetic analytical model for SOL plasmas that overcomes the limitations of fluid and kinetic models. Our model is based on a full-f approach, and employs a full Coulomb collision operator. By porting the Coulomb collision operator from pitch angle to a guiding center coordinate system, a moment hierarchy is obtained. This allows the inclusion of kinetic effects while retaining a correct description of collisional effects. By separating between parallel and perpendicular directions, the model is suitable for being implemented in a turbulence code. In fact, it can exploit the large difference present between the parallel and perpendicular scale lengths, allowing therefore the use of coarse numerical grid in the direction of the magnetic field.

The newly-developed model has been analysed in the large collisionality limit, and shown to retrieve, and improve, the widely-used drift-reduced Braginskii equations. The linearized version has also been studied and shown to capture well known collisional and collisionless modes. Finally, the derivation of the present model illustrates how a fully gyrokinetic model for the SOL might be obtained.