Multi-species Gyro-kinetic Momentum Transport Modeling with the Trapped Gyro-Landau Fluid Model*

G.M. Staebler, R.E. Waltz and J.E. Kinsey

General Atomics, PO Box 85608, San Diego, California 92186-5608 USA

Impurity ions usually make a negligible contribution to energy and particle transport because of their small densities. However, impurities can make a significant contribution to toroidal momentum transport since it scales like their mass times density. Hence, it is essential to include kinetic impurity ions in order to predict momentum transport in tokamaks.

The first applications of the trapped gyro-Landau fluid (TGLF) model [1] to multi-species (electron, deuterium, carbon 6+) multi-channel (particle, energy, momentum) transport modeling of experiments will be presented. The TGLF model has recently been extended to include the Coriolis pinch [2] parallel and $E \times B$ Doppler shear [3]. The $E \times B$ Doppler shear is included in the linear eigenmode wavefunction through a model for the radial wavenumber induced by the shear in the $E \times B$ Doppler shift. The parallel velocity and parallel velocity shear can be different for each species of the plasma so that the diamagnetic and neoclassical poloidal flow contributions can be included. The process of validating the TGLF predicted plasma profiles including the toroidal rotation starts with L-modes and H-modes with unbalanced neutral beam injection. It will be shown that the level of momentum transport predicted by TGLF for the discharges tested is in reasonable agreement with the data when both main ions and impurities are included. With the ability to inject neutral beams in either toroidal direction, the DIII-D tokamak has collected data over a range of torques. The low torque data is particularly challenging for transport modelling [4]. It will be shown that TGLF predicts a net toroidal rotation even with zero external torque. However, this "spontaneous" rotation depends on a multitude of effects of similar size including the shear in the diamagnetic drifts that involve the second derivative of the temperature and density. This makes the calculation of the low rotation profile intrinsically non-local. At high torque, the momentum transport is inadequate to prevent supersonic toroidal rotation violating the low mach number assumption of the theory. Adding the high mach number effects to TGLF including centrifugal force trapping [5] is in progress.

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