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Transport Equations In Tokamak Plasmas[1]

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Tokamak plasma transport equations are usually obtained by flux surface averaging the collisional Braginskii equations. However, tokamak plasmas are not in collisional regimes. Also, ad hoc terms are added for: neoclassical effects on the parallel Ohm's law (trapped particle effects on resistivity, bootstrap current); fluctuation-induced transport; heating, current-drive and flow sources and sinks; small B field non-axisymmetries; magnetic field transients etc. A set of self-consistent second order in gyroradius fluid-moment-based transport equations for nearly axisymmetric tokamak plasmas has been developed recently using a kinetic-based framework. The derivation uses neoclassical-based parallel viscous force closures, and includes all the effects noted above. Plasma processes on successive time scales (and constraints they impose) are considered sequentially: compressional Alfvén waves (Grad-Shafranov equilibrium, ion radial force balance); sound waves (pressure constant along field lines, incompressible flows within a flux surface); and ion collisions (damping of poloidal flow). Radial particle fluxes are driven by the many second order in gyroradius toroidal angular torques on the plasma fluid: 7 ambipolar collision-based ones (classical, neoclassical, etc.) and 8 non-ambipolar ones (fluctuation-induced, polarization flows from toroidal rotation transients etc.). The plasma toroidal rotation equation [1] results from setting to zero the net radial current induced by the non-ambipolar fluxes. The radial particle flux consists of the collision-based intrinsically ambipolar fluxes plus the non-ambipolar fluxes evaluated at the ambipolarity-enforcing toroidal plasma rotation (radial electric field). The energy transport equations do not involve an ambipolar constraint and hence are more directly obtained. The resultant transport equations will be presented and contrasted with the usual ones.

[1] J.D. Callen, A.J. Cole, C.C. Hegna, "Toroidal Rotation In Tokamak Plasmas," to be published in Nuclear Fusion.

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