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Drift-Ordered Fluid Equations for Flute-Like Modes in Low-β Collisional Plasma with Equilibrium Pressure Pedestals*

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Abstract

Starting from modified Mikhailovskii-Tsypin fluid equations [1] (Braginskii-like equations [2] but with temperature gradient effects properly accounted for), equations are derived describing flute-like fluctuations ($k_\parallel/k_\perp \sim \varepsilon << 1$) in a low-β ($\beta \equiv 8\pi(p_e+p_i)/B^2 << 1$), magnetized ($\delta_j \equiv \rho_j/L_f \sim k_\perp\rho_j << 1$) collision-dominated ($\Delta_j \equiv \lambda_j/L_s \sim k_\parallel\lambda_j << 1$) plasma possessing two independent equilibrium length scales, L_s and L_f ($\varepsilon \equiv L_f/L_s << 1$). Here, p_e and p_i are electron and ion pressure, respectively, B is magnetic field, $\rho_j \equiv v_{Tj}/\Omega_j$ is gyro-radius and $\lambda_j \equiv v_{Tj}/\nu_j$ is mean-free path with v_{Tj} thermal speed, Ω_j gyro-frequency and ν_j collision frequency for species j ($j = e, i$). The slow length scale, $L_s \sim k_\parallel^{-1}$, is associated with gradients and curvature of the equilibrium magnetic field, whereas the fast length scale, $L_f \sim k_\perp^{-1}$, is associated with sharp radial pedestal gradients of plasma pressure, density and so on. Additional assumptions, $\Omega_j >> \nu_j >> \omega \sim \delta_i^2\Omega_i$ and $V_j/v_{Tj} \sim \delta_j << 1$, are also employed with ω frequency of the fluctuations and V_j the species flow velocity. The resulting equations for plasma density, vorticity (or, equivalently, electrostatic potential), and electron and ion parallel flow velocities and temperatures, supplemented with Ampere's law, modify and generalize the so-called BOUT equations [3] used to model plasma edge turbulence. They also allow recovering standard neoclassical Pfirsch-Schlüter results [4] (such as the equilibrium ion flow velocity, but not the equilibrium radial electric field) when used to describe axisymmetric toroidal plasma equilibria in the limit of $\delta_i << \Delta_i$, and generalize these results for $\delta_i \sim \Delta_i$.

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