In tokamak plasmas the relative density fluctuation amplitudes increase monotonically from the core to the edge. While in the tokamak core they are less than 0.04% the density, at the edge they reach amplitudes of 5%. The reason for this is flow shears emerging at the LCFS, which are not captured by delta-f gyrokinetic or gyrofluid models. These effects are not captured by a hard-edge delta-f gyrokinetic or gyrofluid model, which is why we consider the development of an electromagnetic full-F gyrokinetic theory. This model is usually coupled to field-aligned flux coordinates, exploiting a minimal parallel resolution due to the flute mode character of microturbulence. However, these coordinates exhibit nonorthogonality and anisotropy near the LCFS as well as singularities due to the flute mode character of microturbulence. The FCI approach gets rid of difficulties arising from flux coordinates. The gyrofluid model is derived from the full-F gyrokinetic theory, allowing the treatment of large flow shears and high amplitude plasma blobs.

The general perpendicular Laplace operator:

\[ \frac{\partial^2}{\partial \psi^2} = \frac{1}{B} \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

Three dimensional full-F two field gyrofluid model

We present an isothermal electromagnetic full-F two field gyrofluid model in an axisymmetric low-beta tokamak. This work was partly supported by the Austrian Science Fund (FWF) Y398; by the Austrian Ministry of Science BMWF as part of the UniInfrastrukturprogramm. The polarisation equation

\[ \psi = \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial \psi}{\partial \psi} \right) + \sum_{f,g} \left[ q_f N \Gamma_{fg} \right] \]

The energy is conserved up to dissipative terms

\[ \frac{dE}{dt} = \frac{1}{2} \sum_f \left( T_N \ln(N) + \frac{1}{2} m_N U_f^2 + \frac{1}{2} m_N \frac{\partial \psi}{\partial t} + \frac{\nabla \cdot A_f}{\rho} \right) \]

Flux coordinate independent approach

The flux-coordinate independent (FCI) field-aligned approach gets rid of difficulties arising from flux coordinates. The FCI approach relies on cylindrical coordinates \((R, \phi, Z)\) and computes the parallel derivative by integrating the equations of a magnetic field line. The parallel derivative is

\[ v_{\parallel} = v_{\phi} \left( \frac{1}{B} \frac{\partial}{\partial \phi} \right) \]

The poloidal gyrokinetic equation:

\[ \nabla \cdot \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

The induction equation:

\[ \nabla \cdot A_f = -j_f = -j_0 \sum_f \left[ q_f (1 / N) \right] \]

close the gyrofluid model.

Energy conservation

The general perpendicular Laplace operator:

\[ \frac{\partial^2}{\partial \psi^2} = \frac{1}{B} \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

Flux coordinate independent full-F gyrofluid model in toroidal geometry

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Full-F two field gyrofluid model

Zeroh gyromoment equation

\[ \frac{\partial N}{\partial t} = \frac{1}{B} \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial N}{\partial \psi} \right) - \nabla \cdot V_f - \frac{1}{2} m_N \frac{\partial}{\partial t} \frac{1}{B^2} \frac{\partial}{\partial \psi} \frac{1}{B^2} \frac{\partial}{\partial \psi} \]

First gyromoment equation

\[ \nabla \cdot \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

The parallel derivative operator is

\[ \frac{\partial}{\partial \psi} = \frac{1}{B} \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

The flux-coordinate independent full-F gyrofluid model in toroidal geometry

The general perpendicular Laplace operator:

\[ \frac{\partial^2}{\partial \psi^2} = \frac{1}{B} \frac{\partial}{\partial \psi} \left( \frac{1}{B^2} \frac{\partial}{\partial \psi} \right) \]

1. Combination of already implemented X-point equilibria with scrape-off-layer boundary conditions to study formation of high amplitude blobs
2. Investigation of strong shear flows and FLR effects on the turbulent structure formation

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References


First numerical results

Here we show numerical results of the electrostatic model with cold ions for a small shaped tokamak with an equilibrium with drift scale \(\rho_d = 0.17\), \(\varphi_0 = 0.1\), \(\beta_0 = 0.6\), elongation \(\kappa = 1.7\) and triangularity \(\delta = 0.34\).