Plasma multiphysics model (FM-WP2)

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Limitations of current model

- Homogeneous, helical (or straight) magnetic field
- No intra-species collisions
- Assumed Boltzmann electron response
- Simple wall boundary condition
- Electrostatic fluctuations
- Simple models for collisions with neutrals

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Unresolved numerical issues

- Current implementation of moment kinetic equations incompatible with wall BCs
- Inclusion of radial electric field leads to poor convergence near walls
- Parallelism of code could be improved?
- Anything else?

More realistic magnetic field geometry

- Keep helical geometry, but allow B=B(r,z)
- Requires treatment of non-periodic radial BC
- Introduces magnetic drifts and shear into the model
- New physics + sets up machinery for coupling to equilibrium solvers
- Allows for direct comparisons with established fluid (e.g., BOUT++) and kinetic (e.g., GKEYLL) codes

Dynamically evolved electrons

- Extant codes either use small term to solve for potential (via polarization density) or must solve iteratively:

$$\frac{\partial f_{i,e}}{\partial t} = H[f_{i,e}, \phi];\ \int d^3v\, f_e = \int d^3v\, f_i + \epsilon\phi$$

- No explicit expression for electrostatic potential
- Rapid electron motion along field lines → small time steps
- Boltzmann model for electrons avoids possible numerical issues associated with evolution

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- We propose two approaches:
  - Treat electrons as a fluid (Braginskii closure and/or mass ratio expansion)
  - Moment-kinetic model with mass ratio expansion

Collisions between charged particles

- Wide range of collisionalities present in edge plasma: from collisional near material boundary to ~collisionless near core
- Need to account for charged particle collisions, at least in intermediate region between fluid limit and collisionless limit
- Full Landau operator is nonlinear, integrodifferential
- Propose to explore hierarchy of models of increasing complexity: Krook, pitch-angle scattering, energy diffusion, conserving corrections

Miscellaneous related issues

- Transition between open and closed field line regions
- Transition between fluid and kinetic treatments
- Can moment kinetics be made to work with wall BC?
- More sophisticated kinetic wall BCs
- Parallelization/memory optimization
- Addition of further unit, integrated, and regression tests