Simulation of Interpenetrating Plasmas in 1D with a Multifluid Approach

**Motivation**

Inertial Confinement Fusion: Colliding plasmas from hohlraum wall and capsule
- Interpenetration of plasma flows from capsule and hohlraum wall
- Large range of $Z$: 2 $\leq Z \leq 60$
- Supersonic flows ($\Delta u = 10^5$ cm/s)
- Species separation inside target capsule

Basic Physics Experiments
- Astrophysics
- Multifluid phenomena that we want to model

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density gas fill
- Inter-penetrating plasmas
- Plasma species separation

Multifluid Model
- **Distinct flows** for each ion species and electrons
- All-species coupling via friction (collisions and kinetic processes) and electric fields
- Ion species can separate if friction weak & charge/mass ratios differ

Inviscid Euler equations for each species $\alpha = 1, \ldots, n_s$

\[
\frac{\partial \rho_\alpha}{\partial t} + \nabla \cdot (\rho_\alpha \mathbf{u}_\alpha) = 0
\]

\[
\frac{\partial \rho_\alpha \mathbf{u}_\alpha}{\partial t} + \nabla \cdot (P_\alpha + \rho_\alpha \mathbf{u}_\alpha \otimes \mathbf{u}_\alpha) = -Z_\alpha \rho_\alpha \nabla \phi + \sum_{\beta \neq \alpha} R_{\alpha,\beta}
\]

Poisson equation for electrostatic potential

\[
\nabla^2 \phi = 4\pi \left( n_e - \sum_\alpha Z_\alpha n_\alpha \right)
\]

Frictional drag

\[
R_{\alpha,\beta} = m_\alpha n_\alpha u_{\alpha,\beta} - R_{\beta,\alpha}
\]

**1D Results – Quasi-neutral Plasmas, Inertia-less and Isothermal Electrons**

Finite-volume code for $n$ fluids
- Applied to simulate colliding plasmas
- 5th order WENO scheme for spatial discretization, 4th order explicit Runge-Kutta method for time integration

**Why Not Single Fluid?**

Single-fluid simulation of colliding carbon plasma streams
- **Interaction between species**
- Frictional heating and thermal equilibration
- Unphysical solution
- Expansion fan inflows at $x = 0$, 1
- Vacuum inside the domain

**Current and Future Work**
- Develop high-order finite-volume code for the 3D multifluid equations (with AMR)
- Include ion and electron heat conduction and inverse Bremsstrahlung heat source
- Develop reduced models to incorporate kinetic effects

**References and previous work:**
- S. Le Pape et al., APS DPP Annual Meeting (2016).

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