COMPLETING DENSITY EVOLUTION DEVELOPMENT IN NIMROD

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- In NIMROD, having *n* evolve into a 3D distribution requires the ability to solve 3D matrices.
  - Semi-implicit and implicit aspects of the algorithm put $n(\mathbf{x})$ on the lhs of equations.
  - 3D matrices are solved in parallel with a matrix-free approach.
  - Development for the **V**-equation was completed at LANL.

- The form of the temperature equations derived from taking moments of the distribution functions has *n* in the thermal conduction term (for $\mathbf{q} \Rightarrow -n\underline{\underline{\chi}} \cdot \nabla T$ and others). Since this term needs to be implicit, it must appear on the lhs.

- The NIMROD implementation with separate electron and ion temperatures (if desired) is complete except for viscous heating and thermal equilibration.

There will be many options (too many?) for the temperature equations:

- p_model='aniso1'

$$n\frac{\partial T}{\partial t} - \nabla \cdot n\underline{\underline{\chi}} \cdot \nabla T = -n\mathbf{V} \cdot \nabla T + (\gamma - 1)\left[-nT\nabla \cdot \mathbf{V} + Q/k - \Pi : \nabla \mathbf{V}/k\right]$$

  n may be fixed, $\langle n \rangle$, or $n(\mathrm{R}, \mathrm{Z}, \varphi)$.
  - Parallel and perpendicular diffusivities for the two species are specified separately.

- p_model='isotropic'='iso'

$$\frac{\partial T}{\partial t} - \nabla \cdot \chi \nabla T = -\mathbf{V} \cdot \nabla T + (\gamma - 1)\left[-T\nabla \cdot \mathbf{V} + Q/nk - \Pi : \nabla \mathbf{V}/nk\right]$$

  - Here, the scalar χ is taken to be a temperature diffusivity.

- p_model='adiabat'

$$\frac{\partial T}{\partial t} = -\mathbf{V} \cdot \nabla T + (\gamma - 1)\left[-T\nabla \cdot \mathbf{V} + Q/nk - \Pi : \nabla \mathbf{V}/nk\right]$$

  - Heating terms can be used despite the name.

- p_model='isothermal'

$$\frac{\partial T}{\partial t} = -\mathbf{V} \cdot \nabla T + (\gamma - 1)\left[Q/nk - \Pi : \nabla \mathbf{V}/nk\right]$$

- Single or two temperatures.

- Continuity is required for nonzero-beta simulations.

- Density diffusion or sources and sinks will be required for simulating transport time-scales. (??)