Electron viscosity

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Electron momentum equation

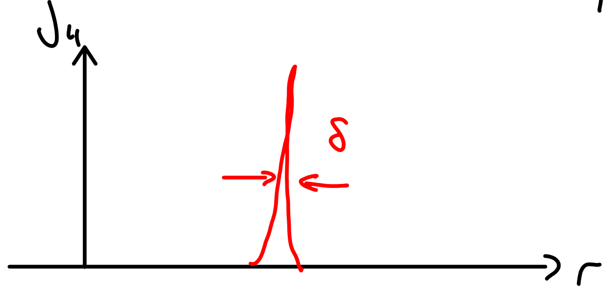
friction

$$m_e\left(\frac{\partial}{\partial t}(n\underline{v}_e) + \nabla\cdot(n\underline{v}_e\underline{v}_e)\right) = -en(\underline{E}+\underline{v}_e\times\underline{B}) - \nabla\cdot\underline{\underline{P}}_e + \underline{R}_e$$

$$\underline{\underline{P}}_e = p_e\underline{\underline{I}} + \underline{\underline{\Pi}}_e$$

$\nabla\cdot\underline{\underline{\Pi}}_e$ has parallel and perpendicular components

η_e^0 $\quad\quad$ η_e^1



$$\eta_e^1 = 0.51\,\frac{neT_e}{\Omega_e^2\,\tau_e}$$ perpendicular viscosity

$$-\nabla\cdot\underline{\underline{\Pi}}_e \simeq \eta_e^1\,\nabla^2\underline{v}_e$$

compare to friction force

resistivity

$$\underline{R}_e = \eta_\parallel e n\underline{J} - 0.71\,n\nabla T_e$$

thermal force

S-H: $\eta_{\parallel} = \dfrac{m_e}{1.96 n e^2 \tau_e}$

$$\underset{\sim}{E} + \underset{\sim}{V_e} \times \underset{\sim}{B} = \eta_{\parallel} \underset{\sim}{J} - \underbrace{\frac{\eta_1^e}{e^2 n^2}} \nabla^2 \underset{\sim}{J} + \ldots \left(\frac{\partial}{\partial t}\right)$$

$V_i \simeq 0$

m_e small

$\underset{\sim}{J} \simeq -en\underset{\sim}{V_e}$

$$0.51 \frac{T_e}{e n \Omega_e^2 \tau_e} \simeq \eta_{\parallel} \rho_e^2$$

electron gyro-radius

$$\underset{\sim}{E} + V_e \times \underset{\sim}{B} = \eta_{\parallel} \underset{\sim}{J} - \underbrace{\eta_{\parallel} \rho_e^2 \nabla^2 \underset{\sim}{J}} + \ldots$$

$\rho_e << L$ so hyper-resistive term small

<u>but</u>

1) can be enhanced by electron fluctuations or turbulence

2) If small scale structures (current sheets) are created e.g. forced reconnection - can become important

3) often kept in numerical simulations to help damp small-scale structures