**The effect of anomalous electron viscosity on magnetic reconnection***

Ilon Joseph and Xueqiao Xu
Lawrence Livermore National Laboratory, Livermore, California, 94551

Anomalous electron viscosity has been invoked to explain magnetic reconnection events both in the core [1] and at the edge [2] of fusion plasmas. Kinematic electron viscosity $\mu_e$ is equivalent to hyper-resistivity $\eta_H=\mu_e d_e^2=2.8\text{x}10^{-6}\mu_e\,(n_e/10^{19}\text{m}^{-3})$, where $d_e$ is the electron skin depth. If set by anomalous processes [3], $\mu_e$ may increase with temperature as in gyro-Bohm scaling and could achieve values on the order of ~1 $m^2$/s at the plasma edge. Thus, one expects that hyper-resistivity will dominate resistivity, $\eta_R=0.021$ $m^2$/s $T_{keV}^{-3/2}$, at small enough distances and high enough temperatures. For the parameters above, hyper-resistivity dominates for spatial scales below $(\mu_e/\eta_R)^{1/2}d_e$~1 cm.

Hyper-resistivity can increase the rate of reconnection $\gamma$ by increasing the width of the reconnection zone $\delta$ relative to its length $L$. If plasma flows out of the reconnecting layer at the Alfvén speed $V_A$, conservation of mass limits the reconnection rate by the aspect ratio of the layer $\gamma L/V_A\sim\delta/L$. Hyper-resistivity increases both scales to $S_H^{-1/4}$ where the hyper-Lundquist number is $S_H\sim L^3V_A/\eta_H$ instead of $S_R^{-1/2}$ where the resistive Lundquist number is $S_R\sim LV_A/\eta_R$. If the reconnecting current sheet itself becomes unstable to secondary tearing [4], the hyper-resistive "plasmoid" instability will develop even finer scales $S_H^{-5/16}$ and grow at super-Alfvénic rates $S_H^{3/16}$.

The stability borders of hyper-resistive modes generally differ from their resistive counterparts. For example, the response to an external magnetic perturbation will be ideal in a plasma that is rotating faster than a critical frequency [4]. The critical frequency is smaller in the hyper-resistive case, $S_H^{-1/5}$ rather than $S_R^{-1/3}$ when inertia dominates viscosity, and so, less reconnection is expected to occur.

[1] X.Q. Xu, B. Dudson, P. B. Snyder, et al., Phys. Rev. Lett. **105**, 175005 (2010).
[2] P. K. Kaw, E. J. Valleo and P. H. Rutherford, Phys. Rev. Lett. **43**, 1398 (1979).
[3] H. Biglari and P.H. Diamond, Phys. Fluids B **5**, 3838 (1993).
[4] N. F. Louriero, A. A. Schekochihin, S. C. Cowley, Phys. Plasmas **14**,100703 (2007).
[5] R. Fitzpatrick, Phys. Plasmas **5**, 3325 (1998).

*Performed by LLNL under US DOE contract DE-AC52-07NA27344