Stirring Unmagnetized Plasma: dynamos in the Lab

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Dynamos transform kinetic energy in the form of plasma flow into magnetic energy. This talk will focus on progress towards creating a laboratory plasma dynamo in the lab using a new cusp-confinement and electrostatic stirring concept [1]. The nature of a plasma dynamo depends critically upon the magnetic Reynolds number (Rm =VL / eta) and the magnetic Prandtl number Pm = nu/eta = Rm/Re (the ratio of the viscosity to magnetic diffusivity or the ratio of the magnetic Reynolds to fluid Reynolds number). Plasma experiments seem well suited to studying large Rm dynamos with Pm>1.

Recent experiments on a novel plasma device will be described that establish the feasibility of creating a high Rm (large, steady-state, fast flowing, and hot plasma) that is weakly magnetized (never before studied in a laboratory plasma). A 0.7 m diameter unmagnetized cylindrical plasma (confined by a high order ring-cusp magnetic field generated by permanent magnets on the surface of the vessel in a Couette flow geometry) and then stirred using biased electrodes in magnetized edge. The momentum is transported inward through viscosity and the entire plasma rotates as a rigid rotor at speeds up to 4 km/s when neutral charge exchange drag is minimized. The experiments have already achieved *Rm*=30 (comparable to liquid metal experiments). Interestingly, this *plasma viscometer* is now being used to test Braginskii's theory of plasma viscosity in both the magnetized and unmagnetized regime.

A much larger device, the Madison Plasma Dynamo Experiment (the MPDX), is also now operating and is creating a two vortex von Karman flow that should exhibit a growing dynamo eigenmode as well as The MPDX is a 3 meter diameter spherical vacuum vessel that uses an array of 3000 4 kG samarium cobalt permanent magnets, and ~200 kWs of LaB6 hot cathode power to ionizing and heat the plasma; this is now generating a steady-state, hot (20 eV) plasma with densities of 10^{18} m^{-3}. The cathodes have stirred the plasma a speeds of up to 12 km/s (Rm=300, Re=200). Confinement scaling suggests the experiment will be quite capable of accessing the high Pm regime characteristic of galactic dynamos, including turbulent fast dynamos with Rm > 1000 and modest values of Re. Numerical simulations have thoroughly explored several self-exciting dynamo scenarios in the MPDX, and discovered signatures of compressibility and two-fluid effects on dynamo onset.

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[3] I. Khalzov, et. al., *Phys. Plasmas* **19,** 112106 (2012).
[4] C.M. Cooper, et. al., *Phys. Plasmas* **21**, 013505 (2013).