Recent Developments in the Theory of High Magnetic Reynolds Number Dynamos

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In this talk I will review recent trends in the theory of high magnetic Reynolds number dynamos, and present some novel results in mean-field dynamo theory. Throughout, I shall attempt to connect this discussion to topics familiar to fusion plasma physicists, such as zonal flow dynamics, turbulence spreading, etc.

Put simply, the problems of mean-field dynamo theory are concerned with the generation of a mean EMF by turbulence, i. e. $\left\langle \tilde{\mathbf{v}} \times \widetilde{\mathbf{B}} \right\rangle$. In the past years, attention has shifted from kinematic calculations, akin to those familiar from quasilinear theory for plasmas, to self-consistent theories which account for the effects of small scale magnetic fields (including their $\widetilde{\mathbf{J}} \times \widetilde{\mathbf{B}}$ back-reaction on the dynamics) and for the constraints imposed by the topological conservation laws, such as that for magnetic helicity. The upshot of this development is that the traditionally invoked mean-field dynamo mechanism (i. e. the so-called alpha effect) may be severely quenched at modest fields and magnetic Reynolds numbers, and that *spatial transport* of magnetic helicity is crucial to mitigating this quench.

I will introduce and review the situation discussed above, and describe a novel approach to the dynamo problem, in which helicity transport (including both resistive and turbulent mixing), rather than computing $\left\langle \tilde{\mathbf{v}} \times \widetilde{\mathbf{B}} \right\rangle$, is fundamental. Thus, the dynamo problem is seen as one of *helicity transport*, and so may be tackled like other problems in turbulent transport. A key element in this approach is to understand the evolution of the turbulence energy and magnetic helicity profiles in *space*. This forces us to confront the problem of spreading of strong MHD turbulence, and a spatial variant or analogue of the selective decay problem.

Throughtout, I will discuss theoretical concepts and possible numerical experiments which may be used to test them.