JOHNS HOPKINS
Center for Environmental
& Applied Fluid Mechanics

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3:00 PM, 132 Gilman Hall

"The Large Scale Dynamo Problem"

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The generation of large-scale magnetic fields in highly conducting objects, like stars and galaxies, is a longstanding puzzle in astrophysics. Most analyses center on the operation of a kinematic dynamo, in which a turbulent flow with an induced kinetic helicity drives the dynamo process, but this model violates the conservation of magnetic helicity. I will revisit the foundations of mean field magnetic dynamo theory and show that a non-zero magnetic helicity flux will drive large-scale dynamo action with a fast growth rate. Any rotating turbulent system will drive such a flux, even in the absence of a large-scale magnetic field. In an inhomogeneous system, such as a galaxy or a star, this leads to the large-scale separation of magnetic helicity, that dominates the kinematic helicity after about one eddy turn over time, i.e., the kinematic dynamo limit is never realized. When the large-scale magnetic field is weak, its growth rate is limited by the turbulent diffusion of magnetic helicity and/or the local pile-up of magnetic helicity. For stronger large-scale fields the growth rate decreases and reaches saturation when it is balanced by the turbulent diffusion rate. Using a simple one-zone dynamo model we recover a generic prediction for the dependence of the saturated magnetic field on the rotation rate which is consistent with observations of low mass stars. We also find that the alpha-omega dynamo is suppressed when the shear is comparable to the turbulent diffusion rate. The alpha squared dynamo is favored for weaker large-scale magnetic fields and is only suppressed when the rotation rate is comparable to the turbulent diffusion rate. For high rotation rates the large-scale magnetic field reaches equipartition with the turbulent energy density.