Collective Transport in Bilayer Quantum Hall Systems

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Ideal bilayer quantum Hall systems have broken symmetry ground states with spontaneous interlayer phase coherence. These states can be regarded either as pseudospin easy-plane ferromagnets or as condensates of excitons formed from electrons in one layer and holes in the other layer. Two different types of transport experiments in bilayer quantum Hall systems, carried out by the group of Jim Eisenstein at the California Institute of Technology, show quite different behaviors neither of which can be understood using conventional electron transport theory. The two experiments, which we refer to as the drag and tunneling experiments, have current source and drain attached to the same layer and to opposite layers respectively.

I will review efforts by a number of researchers that have achieved a partial understanding of these experiments. I will emphasize the close relationship between these phenomena and other topics of current interest in which the physics is controlled by collective order parameter dynamics, including quasiparticle driven magnetization precession and reversal in itinerant electron ferromagnets and condensate dynamics in cold atom BEC systems. The equivalence between excitonic Bose consensate and easy-plane ferromagnet points of view, even at the microscopic level, in bilayer quantum Hall systems highlights differences in the way in which dissipative collective dynamics is commonly modeled in the two cases. In particular, dc-Josephson-effect-like phenomena, in which a collective phase variable does not decay to its ground state value, have no analog in the collective order parameter dynamics of easy-plane ferromagnets. I will discuss why this difference exists and point out several instances in which experience with bilayer quantum Hall ferromagnets suggests new approaches to the collective dynamics of other ordered systems. I will emphasize that the damping of order parameter dynamics in bilayer quantum Hall systems is anomalous, but a different way than in the dc-Josephson effect case because it is the number of electrons in a layer that is nearly conserved instead of the phase relationship between electrons in different layers.

Finally I will discuss an attempt to understand the tunneling and drag experiments on a common footing. According to this interpretation of the data, long range order across the entire sample is not achieved in current bilayer experiments, even in the limit of zero temperature, because of fluctuations in vortex positions. The interpretation uses experimental data to estimate vortex diffusion constants in bilayer quantum Hall systems.