Disordered Quantum Hall Ferromagnets and Cooperative Transport Anisotropy

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We study the transport properties of a quantum Hall system when two Landau levels with opposite spins and combined filling factor near unity are brought into energetic coincidence using an in-plane component of magnetic field. This work has been largely motivated by recent striking experiments under these conditions [1,2], in which a large resistance *anisotropy* develops at low temperatures. We suggest that the observed anisotropy has a *cooperative* origin and arises from the interplay of the quantum Hall *ferromagnetism* and *disorder*.

We model the crossing Landau levels as Ising quantum Hall ferromagnets, which reflects the dominant role of exchange interactions. A uniaxial spin- or charge-density wave at the point of coincidence could straightforwardly explain the transport anisotropy [1,2]; however, Hartree-Fock calculations including both spin- and charge-density modulations give a fully polarized *homogeneous* ground state at coincidence. We thus rule out stripe phases and formulate a model in which the anisotropic transport occurs along domain walls created by disorder.

We suggest that the resistance anisotropy is associated with *domain formation* induced by a random Ising field arising from *surface roughness.* Ising field fluctuations of this kind are intrinsically endowed with anisotropic correlations. Crucially, by the mechanism we propose,

- transport *anisotropy* is generated by *isotropic* surface roughness acting on the *isotropic* ground state of a clean quantum Hall ferromagnet.

In two dimensions, spatial randomness destroys Ising order by creating domains whose size depends on the strength of disorder. We demonstrate that, in our quantum Hall system, surface gradients of a few tenths of a degree on a scale of 1 μm, typically present in high-mobility samples, yield domains of size $\sim 1\,\mu$m. In our model, dissipation in a multi-domain sample occurs due to a percolation of charge along a network of domain walls. Within this picture, charge transport in high-mobility samples is mediated by *collective* domain-wall excitations (skyrmions bound to the wall).

The orientation and the magnitude of resistance anisotropy, as well as the characteristic onset temperature for strongly anisotropic transport, obtained within our model are as observed in Refs. [1,2]. Part of this work was presented in Ref. [3].

[1] U. Zeitler, H.W. Schumacher, A.G.M. Jansen, and R.J. Haug, Phys. Rev. Lett. **86**, 866 (2001).
[2] W. Pan, H.L. Stormer, D.C. Tsui, L.N. Pfeiffer, K.W. Baldwin, and K.W. West, Phys. Rev. B **64**, 121305 (R) (2001).
[3] J.T. Chalker, D.G. Polyakov, F. Evers, A.D. Mirlin, and P. Wölfle, Phys. Rev. B **66**, 161317 (R) (2002).