Condensed Matter Seminar

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Numerical studies of novel quantum phase and transport phenomena in 2D interacting and disordered systems

Using exact diagonalization method with torus geometry, we numerically study quantum phases in different 2D electron systems. For the Dirac fermions in Graphene system with partially filled N=3 Landau level (LL), our results show that at half-filling, the equal-time density-density correlation function displays sharp peaks at nonzero wavevectors q*. Finite-size scaling reveals that the peak value grows with electron number and diverges in thermodynamic limit, suggesting an instability towards a unidirectional charge density wave. This symmetry-broken stripe phase is found robust against perturbation from disorder scattering, indicating experimentally observable through transport measurements. Associated with the special wavefunctions of the Dirac LL in Graphene, both stripe and bubble phases become possible candidates for the ground state of the Dirac fermions with lower filling factors in the N=3 LL. We also study the conventional 2D electron system with 5/2 fractional quantum hall effect. A model Hamiltonian with the additional three-body (3b) interaction has been investigated. The 3b interaction plays a role in breaking the particle-hole (PH) symmetry of the system and induces a phase transition of the ground state (GS) towards a Pfaffian (Pf) state or its PH conjugate (APf) state depending on the sign of the three-body interaction. The results of the low energy spectrum, the wave function overlap, and the PH parity evolution, have shown strong evidence of the existence of a first order phase transition between the Pf and the APf, with the pure Coulomb system sitting at the critical point of the transition. Modulated by an extra short-range pseudopotential, the above induced Pf or APf system can transfer to the nearby compressible phases with the stripe order or the composite-fermion-liquid (CFL) state.

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