Toward a new theory of the fractional quantum Hall effect

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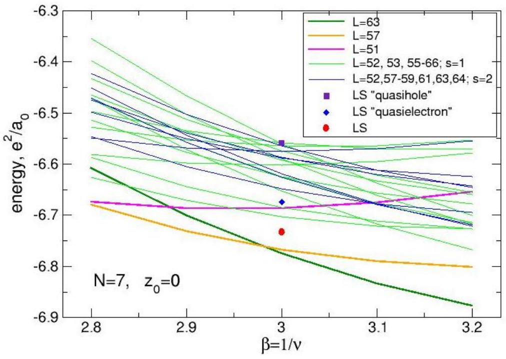
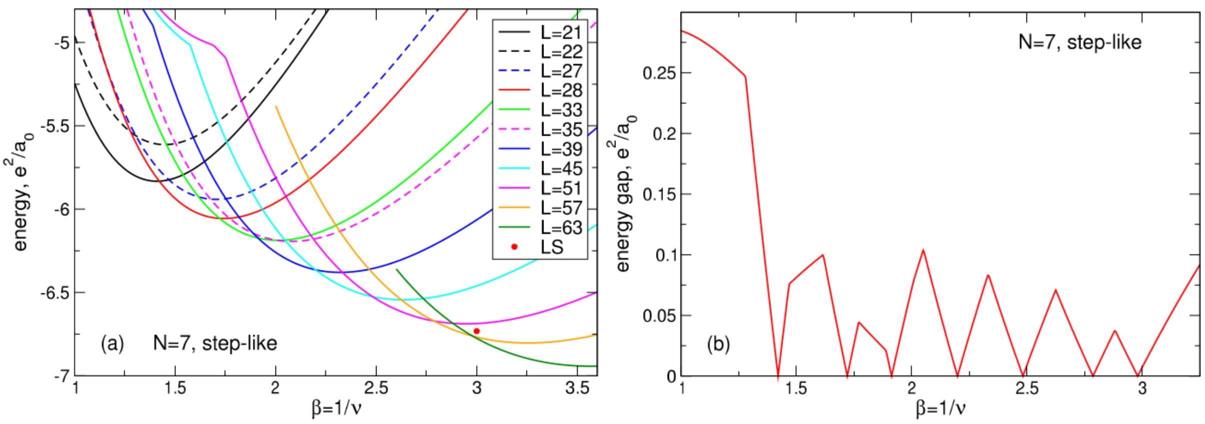
The currently accepted theory of the fractional quantum Hall effect (FQHE) assumes that the ground and the lowest excited states of the FQHE system - the so-called fractionally charged quasiholes and quasielectrons - are described by the wave functions proposed in [1]. However, these wave functions are trial functions and do not satisfy the Schrodinger equation. I performed a detailed analysis of the assertions of the modern FQHE theory and showed that neither the Laughlin state (LS) nor its fractionally charged excitations correspond to physical reality, neither at small number of particles N nor in the thermodynamic limit. For example, the figure on the right shows exactly calculated energy levels of a system of $N = 7$ electrons around the Landau level filling factor $\nu=1/3$ (curves labeled by the total angular momentum L), together with the Laughlin ground (LS) and excited states, shown by points; here $a_0 = (\pi n_s)^{-1/2}$ and n_s is the electron density. The energy of the Laughlin quasihole state is higher than the energies of at least 24 different exact excited states at $N = 7$. In the thermodynamic limit, this number increases to infinity.



I performed exact diagonalization calculations of the energy (figure below) and other physical properties of the ground and excited states of a system of $N \leq 7$ two-dimensional Coulomb interacting electrons in a disk geometry, as a function of the magnetic field B in the range $1/4 \lesssim \nu < 1$. The results show that both the ground and excited states of the system resemble a sliding Wigner crystal whose parameters are influenced by the magnetic field. When the B-field changes, the energy gap between the ground and the first excited states arise and disappear as a result of the competition between repulsive Coulomb forces and compressive action of the magnetic field. The results of this work shed new light on the true nature of the ground and excited states in the fractional quantum Hall effect.

Full details of this work, including criticism of various aspects of modern FQHE theory, can be found in [2].



[1] R. B. Laughlin, *Phys. Rev. Lett.* **50**, 1395 (1983).
[2] S. A. Mikhailov, *Nanomaterials* **14**, 297 (2024).