Linear and nonlinear edge dynamics of trapped fractional quantum Hall droplets

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Abstract

We numerically study the linear and nonlinear edge dynamics of a non-harmonically-confined macroscopic Laughlin quantum Hall fluid with short-ranged interactions and build an analytical simple model which is able to faithfully reproduce all the relevant physics of the system (1).
In particular, we characterize the first corrections to Wen's chiral Luttinger liquid theory: the linear wave dispersion relation get a cubic correction due to velocity gradients at the system's edge and strong bulk correlations extending all the way through the bulk. At the same time, sizable nonlinear effects are found in the dynamics, which have the potential to lead to intriguing wavebreaking dynamics.
The numerically observed features are quantitatively captured by a nonlinear chiral Luttinger liquid quantum Hamiltonian:
the nonlinear dynamical behaviour is mapped onto interactions between the bosonic modes, while the modified linear-waves dispersion is accounted for by an additional quadratic term. The one-dimensional edge-density time evolution reduces to a driven Korteweg-de Vries equation in the semiclassical limit.
Making use of refermionization techniques (2) we show that the charge-zero sector of the theory can be exactly mapped onto a one-dimensional model of massive and interacting chiral fermions; this gives physical insight on the dynamical structure factor, in particular showing that it exhibits a universal power-law behaviour at its thresholds which depends on the filling fraction alone but not on the details of the anharmonic trap, even though an anharmonic trap is required to trigger the power-law behaviour. 1) A. Nardin, I. Carusotto, Linear and nonlinear edge dynamics of trapped fractional quantum Hall droplets, Phys. Rev. A 107, 033320 (2023)
2) A. Nardin, I. Carusotto, soon on arXiv

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