Anyonic Molecules in Atomic Fractional Quantum Hall Liquids: A Quantitative Probe of Fractional Charge and Anyonic Statistics

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Abstract

We study the quantum dynamics of massive impurities embedded in a strongly interacting, two-dimensional atomic gas driven into the fractional quantum Hall (FQH) regime under the effect of a synthetic magnetic field. For suitable values of the atom-impurity interaction strength, each impurity can capture one or more quasihole excitations of the FQH liquid, forming a bound molecular state with novel physical properties. An effective Hamiltonian for such anyonic molecules is derived within the Born-Oppenheimer approximation, which provides renormalized values for their effective mass, charge, and statistics by combining the finite mass of the impurity with the fractional charge and statistics of the quasiholes. The renormalized mass and charge of a single molecule can be extracted from the cyclotron orbit that it describes as a free particle in a magnetic field. The anyonic statistics introduces a statistical phase between the direct and exchange scattering channels of a pair of indistinguishable colliding molecules and can be measured from the angular position of the interference fringes in the differential scattering cross section. Implementations of such schemes beyond cold atomic gases are highlighted, in particular, in photonic systems.

References

[1] A. Muñoz de las Heras et al., Phys. Rev. X, 10 (2020) 041058

Figures

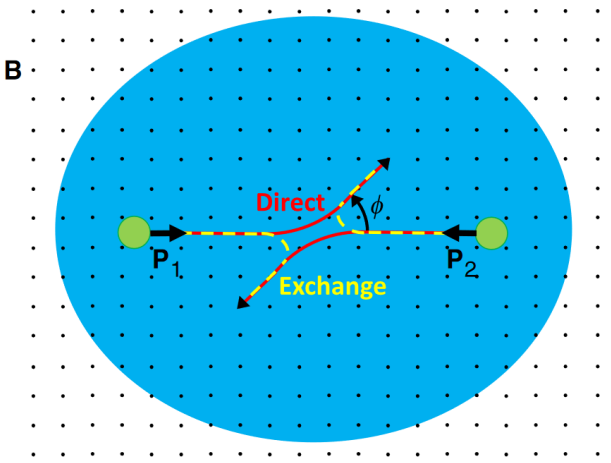

Figure 1: Scattering of two anyonic molecules (green circles) formed by the binding of the same number of quasiholes to a pair of identical impurities in the bulk of a FQH fluid (blue region). The two molecules are given momentum kicks against each other (P1 and P2, respectively). Because of their indistinguishability, two scattering channels contribute to the differential scattering cross section at an angle φ: The two channels are labeled as "direct" (red, solid trajectories) and "exchange" (yellow, dashed ones) and involve a relative phase determined by the anyonic statistics. As one can guess from textbook two-slit interference, information about the statistics can be extracted from the global position of the interference fringe pattern.