Graviton modes in fractional quantum Hall liquids

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Recently, Haldane proposed a new geometrical description for the fractional quantum Hall (FQH) effect, suggesting the existence of a previously overlooked quantum metric. Novel collective excitations called graviton modes (GMs) are proposed as quanta of fluctuations of the metric. Such modes are condensed-matter analogues of gravitons that are hypothetical spin-2 bosons, and could be described by the corresponding Fierz-Pauli field equations in FQH liquids. GMs are characterized by polarized states with chirality of +2 or -2, and energy gaps coinciding with fundamental neutral collective excitations (i.e., magnetorotons) in the long-wavelength limit. However, GMs remain experimentally inaccessible. Here, we observe chiral graviton modes in FQH liquids using inelastic scattering of circularly-polarized light [1]. The experiments are performed in a GaAs quantum well. At filling factor ν = 1/3, the long-wavelength magnetoroton emerges under a specific polarization scheme corresponding to angular momentum -2. Remarkably, the mode chirality remains -2 at ν = 2/5 but becomes the opposite at v = 2/3 and 3/5. The modes have characteristic energies and sharp peaks with marked temperature and filling-factor dependence, corroborating the assignment of the GMs. These observations capture the essentials of the graviton modes and support the new FQH geometrical description.

[1]. J. Liang et al, Nature 628, 78 (2024)