Meron-Pair Excitations in Imbalanced Bilayer Quantum Hall Systems

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The bilayer quantum Hall (BQH) system is exceedingly interesting owing to quantum coherence associated with the spin and layer degrees of freedom[1], where the layer degree of freedom introduces a pseudospin into the system. We study the BQH system by changing the density ratio σ_0 between the two layers, where $\sigma_0 = 0$ ($\sigma_0 = 1$) represents the balanced configuration (the monolayer limit). The BQH system behaves as if it were an easy-plane ferromagnet with pseudospin SU(2) skyrmion excitations at $\sigma_0 = 0$, while it behaves as if it were an easy-axis ferromagnet with spin SU(2) skyrmion excitations at $\sigma_0 = 1$. The activation energy exhibits entirely different behaviors when the parallel magnetic field $B_\parallel$ is applied. It rapidly decreases at $\sigma_0 = 0$, but rapidly increase at $\sigma_0 = 1$. The decrease occurs due to the loss of the exchange energy, while the increase occurs due to the Zeeman energy. We analyze in detail how an SU(2) skyrmion at $\sigma_0 = 0$ evolves continuously into another SU(2) skyrmion at $\sigma_0 = 1$ via an SU(4) skyrmion as σ_0 is increased. An SU(4) skyrmion is constructed by dressing a cloud of spins and pseudspins around an electron or a hole in a microscopic theory. Our theoretical results explain the experimental data[2] quite well.

[1] Z.F. Ezawa, *Quantum Hall Effects* (World Scientific, 2008, 2nd ed.).
[2] A. Sawada et al., Physica E **18** (2003) 118; D. Terasawa et al., Physica E **22** (2004) 52.