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NMR probing of fractional quantum Hall liquid and Wigner solid phases

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Nuclear magnetic resonance (NMR) has played a decisive role in elucidating various spin-related physics in the quantum Hall regime. In this talk, I will present resistively detected NMR (RD-NMR) measurements performed in the millikelvin temperature regime on a high-mobility two-dimensional electron system confined to a GaAs quantum well. The wide range of density tunability provided by the back gate allows us to explore both the first and second Landau levels (LLs), from full depletion to $\nu = 8/3$, at a constant magnetic field of 6.4 T.

Measurements of spin polarization as a function of filling factor via the Knight shift reveal markedly different behavior in the first and second LLs. In contrast to the first LL, where the spin polarization oscillates with ν, the second LL remains fully polarized independent of ν, including not only the quantized Hall states at $\nu = 5/2$, 7/3, and 8/3 but also the non-quantized states between them [1]. The implications of the different behavior is discussed in terms of the composite fermion model.

Furthermore, I will show that NMR can be a sensitive probe of not only the spin, but also the charge degree of freedom in the electron system. This is demonstrated in the fractional as well as integer regime, where striking anomalies in the Knight shift and spectral lineshape appear at low partial filling. Numerical simulations incorporating a spatially varying density landscape resulting from the formation of a Wigner solid reproduce the observed anomalies remarkably well. Our RD-NMR spectra uncover the evolution of quantum electron solids manifested by local density fluctuations that grow as the transition to the liquid phase is approached.

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[1] L. Tiemann, G. Gamez, N. Kumada, and K. Muraki, Science **335**, 828 (2012).