

Quantum Simulation of Spin-Charge Separation

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Models of quantum many-body phases of matter may be realized using fermionic ultracold atoms in place of the electrons, and engineered optical potentials to emulate a crystal lattice. Quantum simulation of this kind takes advantage of the capability to adhere to a theoretical model, while the tunability of model parameters enables quantitative comparison with theory.

As an example, repulsively interacting spin-1/2 fermions confined to one-dimensional (1D) tubes, realize a Tomonaga-Luttinger liquid. The low energy excitations are collective, bosonic sound waves that correspond to either spin-density or charge-density waves that, remarkably, propagate at different speeds. Such a spin-charge separation has been observed in electronic materials, but a quantitative analysis has proved challenging because of the complexity of the electronic structure and the unavoidable presence of impurities and defects in electronic materials. In collaboration with our theory colleagues, we made a direct theory/experiment comparison and found excellent agreement as a function of interaction strength [1]. It was necessary to include nonlinear corrections to the spin-wave dispersion arising from back-scattering, thus going beyond the Luttinger model. More recently, we explored the disruption of spin correlations with increasing temperature [2], an effect that destroys spin-charge separation. We are now working near a p-wave resonance with the goal of realizing p-wave pairs.

1. R. Senaratne, D. Cavazos-Cavazos et al, "Spin-charge separation in a 1D Fermi gas with tunable interactions", *Science* 376, 1305 (2022).
2. D. Cavazos-Cavazos, R. Senaratne, A. Kafle, and R.G. Hulet, "Thermal Disruption of a Luttinger liquid", *Nature Commun* 14, 3154 (2023).

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