Quantum Simulation of Many-Body States of Matter with Ultracold Atoms

R G Hulet[1]

[1]*Rice University, Houston TX, USA*
Contact Email: randy@rice.edu

Models of quantum many-body phases of matter have been realized using fermionic ultracold atoms instead of electrons and engineered optical potentials that emulate a crystal lattice. Quantum simulation of this kind takes advantage of the innate capability to adhere to a theoretical model, while the tunability of model parameters enables quantitative comparison with theory. For 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 to realize p-wave pairs.

References

[1] R Senaratne, D Cavazos-Cavazos, S Wang, F He, Y-T Chang, A Kafle, H Pu, X-W Guan and R G Hulet, Science **376**, 1305 (2022)

[2] D Cavazos-Cavazos, R Senaratne, A Kafle and R G Hulet, Nat. Commun. **14**, 3154 (2023)