Particle, heat and Hall transport in strongly interacting quantum gases

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Transport is the defining property of states of matter, but often the most difficult to understand. Strongly interacting Fermi gases are especially challenging, despite their ubiquitous presence across many fields of physics. Experiments on ultracold fermionic atoms allow the direct measurement of transport properties in ideal model systems where the Hamiltonian is precisely known while transport properties are difficult to calculate theoretically. In this talk I will present our recent experiments on several platforms, the Unitary Fermi gas [1], Bose-Fermi mixtures [2], the Fermi-Hubbard model [3] and rotating quantum gases [4]. One focus will be on the question of how to directly measure heat in quantum gases [5], and watch its ballistic propagation through superfluids, that is second sound. Another recent avenue is the measurement of Hall transport, accomplished via a new method, geometric squeezing [4], that is based on the non-commutativity of spatial coordinates under rotation. The method prepares rapidly rotating Bose-Einstein condensates in a single Landau gauge wavefunction, observed to have a minimal transverse width given by the zero-point cyclotron motion. This system allows studying the fate of interacting condensates under the sole influence of a synthetic magnetic field, and reveals magneto-hydrodynamic instabilities of bosonic quantum Hall states.

[1] Universal Sound Diffusion in a Strongly Interacting Fermi Gas
Parth B. Patel, Zhenjie Yan, Biswaroop Mukherjee, Richard J. Fletcher, Julian Struck, Martin W. Zwierlein
Science, to appear (2020), arXiv:1909.02555

[2] Bose polarons near quantum criticality
Zoe Z. Yan, Yiqi Ni, Carsten Robens, Martin W. Zwierlein
Science, 368, 190-194 (2020), arXiv-Link

[3] Spin Transport in a Mott Insulator of Ultracold Fermions
Matthew A. Nichols, Lawrence W. Cheuk, Melih Okan, Thomas R. Hartke, Enrique Mendez, T. Senthil, Ehsan Khatami, Hao Zhang, Martin W. Zwierlein
Science 363, 383 (2019), arXiv-Link

[4] Geometric squeezing into the lowest Landau level
Richard J. Fletcher, Airlia Shaffer, Cedric C. Wilson, Parth B. Patel, Zhenjie Yan, Valentin Crépel, Biswaroop Mukherjee, Martin W. Zwierlein
arXiv:1911.12347 (Science, to appear 2020/21)

[5] Doublon-Hole Correlations and Fluctuation Thermometry in a Fermi-Hubbard Gas
Thomas Hartke, Botond Oreg, Ningyuan Jia, Martin Zwierlein
PRL 125, 113601 (2020) arXiv-Link