Josephson oscillations and superfluidity in strongly correlated 2D Fermi gases

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Reducing the dimensionality of a quantum system from three to two dimensions significantly modifies its physical properties. One striking effect is the increased role of fluctuations in low-dimensional systems, which prevents long-range phase coherence and makes 2D the marginal dimension for the existence of superfluidity. Hence it is quite surprising that in all known ambient-pressure high -Tc materials superconductivity occurs in two-dimensional structures, such as the copper-oxide layers in cuprates.

Understanding such strongly interacting 2D systems is very challenging due to the interplay of strong local correlations and enhanced long-range fluctuations.

In this colloquium I will introduce ultracold 2D Fermi gases, which have emerged as a clean model system to study superfluidity in reduced dimensions, driven largely by seminal work by the groups of S. Jochim and T. Enss. In these systems, it is possible to tune the interaction strength and hence investigate superfluids in the crossover from weakly bound Cooper pairs to tightly bound dimers.

I will report on our recent realization of a Josephson junction in such a 2D Fermi gas [1]. These measurements clearly demonstrate phase coherence across the junction and were inspired by the pioneering work on Josephson oscillations in the Oberthaler group.

Furthermore, I will show how we were able to demonstrate superfluidity in these ultracold 2D Fermi gases for the first time [2].

[1] N. Luick et al., Science 369, 89 (2020)

[2] L. Sobirey et al, arxiv:2005.07607 (2020)