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Universal Spin Transport in Strongly Interacting Fermi Gases[1]

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Ultracold gases of fermionic atoms have emerged as a unique platform to study strongly interacting fermion systems. Here we study spin transport in a two-state mixture of fermionic atoms near a Feshbach resonance. Starting with two separate spin domains in an atom trap, we observe the subsequent evolution of the spin mixture towards the eventual ground state, a superfluid of fermion pairs. Initially, the gas clouds of unlike spins almost perfectly bounce off each other, despite densities a million times thinner than air. Only over several seconds, about 100 000 collision times, the spins slowly diffuse into each other and, below a critical temperature, form a superfluid of fermion pairs. We determine the transport properties in this gas as a function of interaction strength and temperature. In particular, we find the spin diffusion coefficient in the strongly interacting, degenerate regime to take on the universal value for a "perfect fluid", $D \simeq \hbar/m = \frac{(100\mu\mathrm{m})^2}{\mathrm{s}}$, where m is the mass of the ^{6}Li atoms. At high temperatures, we find the universal law $D = \alpha \frac{\hbar}{m} (T/T_F)^{3/2}$ with a constant α. The ratio of spin conductivity and spin diffusion coefficient yields the spin susceptibility in these gases, showing the Curie law at high temperatures and a departure from the compressibility at low temperatures, that we interpret as a signature for entering the Fermi liquid regime. Our transport experiments near and far equilibrium have implications on other strongly interacting Fermi systems, suggesting a fundamental lower limit to the spin diffusion coefficient, in the absence of localization, on the order of $\hbar/m$ - a conjecture already made by Onsager. Our spin susceptibility measurements appear to exclude a ferromagnetic ground state on the repulsive side of the Feshbach resonance.

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