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Transport in the quantum critical regime

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In this talk I will explain the relevance of the quantum critical point for the phase diagram of the unitary Fermi gas, briefly review theoretical approaches, and present results for the shear viscosity and spin diffusion in strongly interacting Fermi gases. The unitary Fermi gas describes strongly interacting fermions ranging from ultracold atoms near a Feshbach resonance to dilute neutron matter, which share a common universal phase diagram. The behavior at finite temperature is governed by a quantum critical point (QCP) at zero temperature and zero density, and observables can be expressed by universal scaling functions of the distance from the critical point. In the quantum critical regime above the QCP, thermal and quantum fluctuations are equally important, and the absence of a small parameter makes the computation of critical properties demanding. I will mention two theoretical approaches to transport properties in this regime: the large-N expansion in the number of fermion flavors allows for a systematic and controlled expansion even at strong coupling and elucidates the importance of medium effects on scattering. Second, the Luttinger-Ward, or self-consistent T-matrix approach goes beyond the quasiparticle picture and also explains universal high-energy tails. I will present results on the shear viscosity, or internal friction, for mass transport and show that the strongly interacting Fermi gas is an almost perfect quantum fluid. On the other hand, if particles of different spin move in opposite directions, the dynamics are governed by spin diffusion. One can distinguish longitudinal diffusion, when atomic clouds of different spin collide, and transverse diffusion, when the magnetization is wound up in a helix in a spin-echo experiment. Medium scattering and spin rotation have a strong effect on spin diffusion, and I will discuss how spin transport becomes very slow at strong coupling in the quantum degenerate regime and reaches a quantum limit of diffusion.