

High-Temperature Superconductivity and the Catch-22 Conundrum

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The phase diagram of hole-doped cuprates holds many of the keys to unlocking the mystery of high-temperature superconductivity. Its principal elements; the antiferromagnetic Mott insulator at half-filling, the pseudogap phase, the strange metallic region, the superconducting dome, the phase-fluctuation regime and the highly correlated Fermi-liquid at large doping, must all be incorporated into any viable theory of the doped copper-oxide plane. The traditional approach has been to consider the phase diagram from the perspective of half-filling and the effect of increasing the hole density p within the antiferromagnetic background. This approach leads typically to comparisons with quantum critical metals, with some energy scale vanishing, e.g. in tandem with the exchange interaction J , at a quantum critical point ($p = p_c$). This approach also focuses on the *formation* of quasiparticles and the emergence of superconductivity out of the correlation-driven insulating state.

In this Lecture, I will present an alternative ‘back-door’ approach to this seemingly intractable problem, looking at it from the highly-doped metallic side. Starting with a detailed characterization of the correlated metallic state, its Fermi surface and charge dynamics, we will explore the evolution of the electronic state and the gradual *destruction* of quasiparticles as the carrier density is reduced and superconductivity emerges from the right-hand-side of the phase diagram. Key findings include the growth of a linear-in-temperature resistivity whose magnitude scales with the superconducting transition temperature and which is associated with an anisotropic scattering rate whose momentum dependence mimics that of the *d*-wave superconducting order parameter. Significantly, this additional scattering appears to ‘switch on’ at the edge of the superconducting dome, implying a close and direct correlation between it and the superconducting pairing interaction. Finally, we show that the critical doping level p_c at which superconductivity is maximal, and the pseudogap first appears, coincides with the onset of normal-state decoherence in those quasiparticles most heavily involved in the superconductivity itself. Ironically, the same interaction that first promotes superconductivity ultimately destroys the very quasiparticles needed to form the condensate.