Mott Transition from Spin Liquid to Fermi Liquid in the Spin-Frustrated Organic Conductor $\kappa(ET)_2Cu_2(CN)_3$

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Recommended with a Commentary by Matthew Fisher, KITP, Santa Barbara.

Since the discovery of high Tc superconductivity when Anderson reinvigorated his notion of an RVB spin liquid, finding an experimental example of such an exotic quantum phase of strongly correlated matter has been something of a holy grail. Anderson's original proposal back in 1973 concerned the triangular lattice spin one-half Heisenberg antiferromagnet. Due to the strong geometrical frustration which tends to inhibit magnetic ordering, together with the small spin which amplifies the importance of quantum fluctuations, the triangular lattice was an appealing setting to host a possible RVB phase. Since then, significant theoretical progress has been made, and it is now established that Anderson's original short-range RVB state has a hidden topological order and an emergent Z2 gauge structure, with a gap to all bulk excitations. Moreover, a number of ``toy" lattice spin models have been shown to exhibit such a Z2 spin liquid, as well as a variant of the quantum dimer model on the triangular lattice. Unfortunately, the predominance of the numerical evidence strongly suggests that the simplest nearest-neighbor s=1/2 triangular AFM is actually magnetically ordered (coplanar order), albeit rather weakly.

But in the past several years, two experimental systems have emerged as the leading contenders in the spin liquid search - Cs_2CuCl_4 and an organic material in the κ-BEDT class. Both systems consist of stacks of weakly coupled triangular lattice Mott Hubbard insulators. Moreover, both systems exhibit evidence for low energy or gapless spin excitations, suggestive of a more complicated ``algebraic spin liquid", rather than the spin-gapped short-ranged RVB state. The condmat/0504273 article is the latest in a short series of recent experiments exploring the putative spin liquid in the latter organic material.

Earlier experiments by some of the same authors, employed NMR and uniform magnetization studies to establish an absence of magnetic ordering down to 30mK - quite remarkable given the estimated value of 250K for the dominant exchange interaction. Moreover, the longitudinal NMR relaxation rate $1/T_1$ varied as a power of temperature below about one Kelvin, implying very low energy spin carrying excitations.

In this paper the pressure-temperature phase diagram is explored. With both NMR and resistance measurements, it is established that a moderate pressure (0.3 GPa) drives a weakly first order transition between the putative spin liquid and a conducting metallic phase. The metal appears to be consistent with a Fermi liquid, with T^2 resistance and a constant $1/T_{1T}$ Korringa law. Moreover, the coefficient of the T^2 term in the resistance grows and the Fermi liquid coherence scale diminishes upon approaching the Mott transition from the metallic side. These trends are consistent with the weak first order nature, and suggest the possibility of some critical fluctuations. At the lowest temperatures, the Fermi liquid gives way to a superconductor. On the low pressure side the spin liquid remains magnetically disordered right up to the first order transition.

But perhaps the most striking experimental result is the shape of the phase boundary in the pressure-temperature plane, which has a positive dP/dT slope throughout, indicating that the spin liquid has MORE entropy at low temperatures than the Fermi liquid. This remarkable result suggests that the spin liquid has a plethora of low energy excitations - ``more'' than the particle/hole continuum in the metal. As proposed in two recent preprints (by O. Motrunich cond-mat/0412556 and by S. Lee and P.A. Lee, cond-mat/0502139), a plausible spin liquid with such behavior has a Fermi surface of spinons coupled to a fluctuating U(1) gauge field - essentially the spin-sector of the original Baskaran-Anderson state proposed in the context of the optimally doped cuprates. Future low temperature experiments such as specific heat and thermal transport in this novel spin liquid should give valuable further guidance in discerning the true nature of the underlying quantum state.