^3He **Films as Model Strongly Correlated Fermion Systems:**

Observation of a magnetic quantum critical point

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Recommendation and commentary by Piers Coleman, Rutgers University.

In a report, made jointly at SCES05 in Vienna and at LT24, Orlando, John Saunders and group from Royal Holloway College, UK, tentatively announced the discovery of a new class of two-dimensional helium-3 fluid which forms on graphite and behaves analogously to heavy electron metals. In the bulk, ^3He is *the* historic paradigm for Fermi liquid behavior and anisotropic superfluidity On graphite, adsorbed Helium films form two dimensional quantum fluids, in which the Helium atoms move coherently across the periodic triangular potential of the graphite surfaces. These are very clean, model strongly correlated Fermi systems, with no complications from crystal fields or separate electronic and nuclear contributions to the specific heat. If confirmed, this new discovery is of immense importance, for it provides a completely new setting for the community to examine the unusual strange Fermi fluid that forms around a quantum phase transition.

Earlier work [1] by the Holloway group established that monolayer ^3He films form a Fermi liquid which undergoes a Mott transition into a triangular lattice solid at a critical filling factor $n_{He} \sim 5nm^{-2}$. Using a slightly modified substrate, the same group has now succeeded in adding more ^3He atoms to form a bilayer quantum fluid. The new bilayer system remains a Fermi liquid up to a much higher critical coverage of $9.9nm^{-2}$, where it undergoes a quantum phase transition into a magnetic state. Saunders suggests that the fluid that forms closely resembles a two-dimensional heavy fermion system, in which the lower layer of atoms is an almost localized spin system and the upper layer behaves as a conduction band (Fig. 1.(a)). Zero point "valence fluctuations" between the layers may play an important role, causing spin exchange between the upper and lower fluid that closely resembles the physics of a two dimensional Kondo lattice(Fig 1. (a)). The observed specific heat curves show a maximum T_0 and appears to indicate the presence of an as-yet unexplained gap Δ in the excitation spectrum. Experimentally, as the filling of the second layer is increased, the inverse mass of the Fermi liquid appears to collapse linearly to zero as the critical coverage is approached, while T_0 vanishes with a power law. Mysteriously, the gap appears to drop to zero at a lower value of the filling. (Fig. 1. (b)). This is an exciting new discovery that should

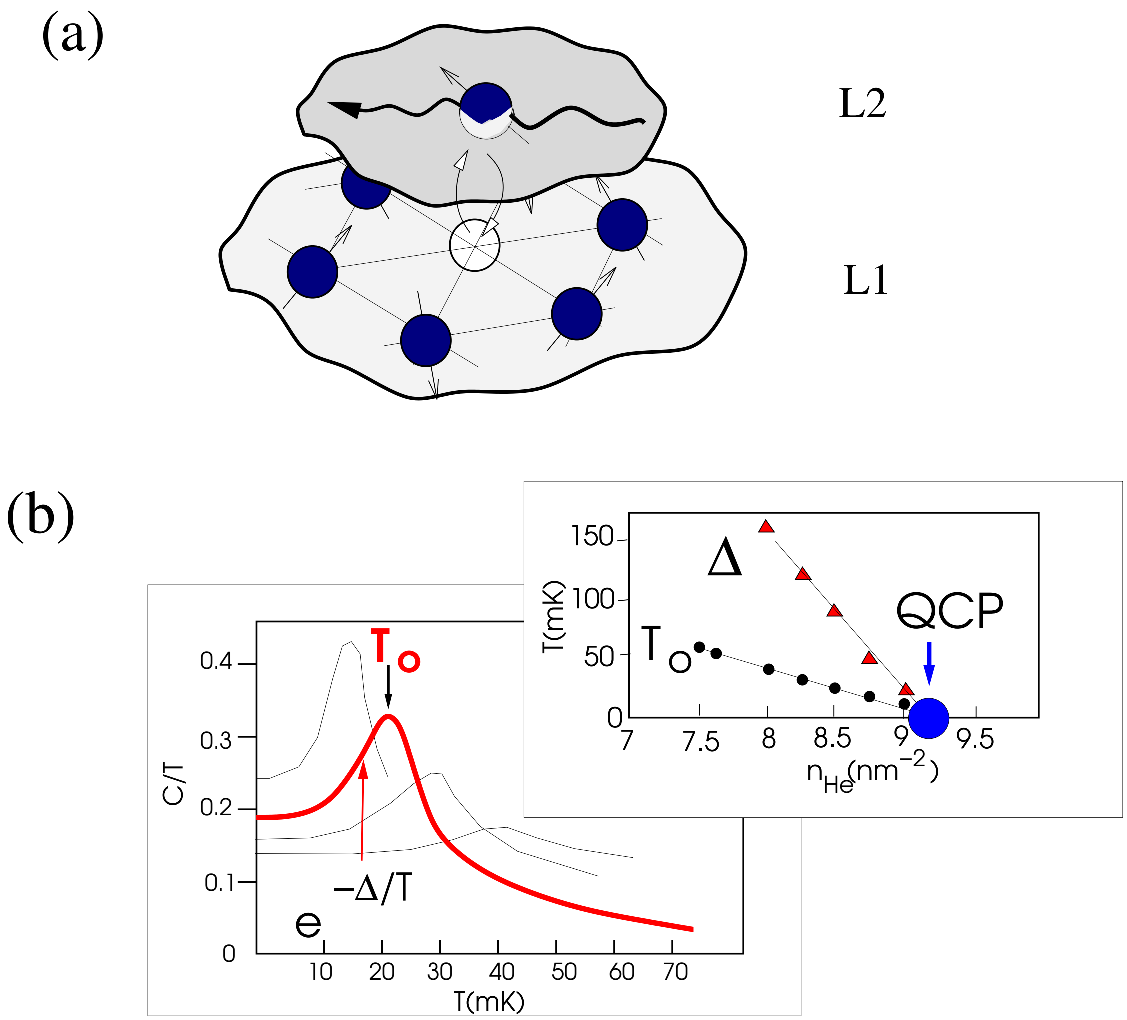

FIG. 1: (a) Schematic of bilayer ^3He, showing almost localized lower layer (L1) of spins and delocalized upper "conduction sea" (L2). Valence fluctuations between the two layers help to melt the lower layer to produce a two dimensional heavy fermion fluid. (b) Sketched evolution of C_v/T [1] as a function of filling, showing peak temperature T_0, and exponential decay $e^{-\frac{\Delta}{T}}$ that are used to define the characteristic energy scales. Inset: collapse of characteristic scales to zero at a quantum critical point where $n_{He} = 9.9\text{nm}^{-3}$.

be a great encouragement to the field, prompting new theoretical work and tending to support the idea that the physics of quantum criticality seen in electronic heavy fermion systems may in fact, be universal to a much broader class of fermionic matter.

[[1] " *Evidence for a Mott-Hubbard Transition in a Two-Dimensional 3He Fluid Monolayer*" A. Casey, H. Patel, J. Nyéki, B. P. Cowan, and J. Saunders, Phys. Rev. Lett. **90**, 115301/1-4 (2003).