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Non-Fermi-liquid d-wave metal phase of strongly interacting electrons

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Nature 493, 39–44 (03 January 2013)

Developing a theoretical framework for conducting electronic fluids qualitatively distinct from those described by Landau's Fermi-liquid theory is of central importance to many outstanding problems in condensed matter physics. One such problem is that, above the transition temperature and near optimal doping, high-transition-temperature copper-oxide superconductors exhibit 'strange metal' behaviour that is inconsistent with being a traditional Landau Fermi liquid. Indeed, a microscopic theory of a strange-metal quantum phase could shed new light on the interesting low-temperature behaviour in the pseudogap regime and on the d-wave superconductor itself. Here we present a theory for a specific example of a strange metal—the 'd-wave metal'. Using variational wavefunctions, gauge theoretic arguments, and ultimately large-scale density matrix renormalization group calculations, we show that this remarkable quantum phase is the ground state of a reasonable microscopic Hamiltonian—the usual t–J model with electron kinetic energy t and two-spin exchange J supplemented with a frustrated electron 'ring-exchange' term, which we here examine extensively on the square lattice two-leg ladder. These findings constitute an explicit theoretical example of a genuine non-Fermi-liquid metal existing as the ground state of a realistic model.

The Josephson heat interferometer

Francesco Giazotto, María José Martínez-Pérez

Nature 492, 401–405 (20 December 2012)

The Josephson effect is perhaps the prototypical manifestation of macroscopic phase coherence, and forms the basis of a widely used electronic interferometer—the superconducting quantum interference device (SQUID). In 1965, Maki and Griffin predicted that the thermal current through a temperature-biased Josephson tunnel junction coupling two superconductors should be a stationary periodic function of the quantum phase difference between the superconductors: a temperature-biased SQUID should therefore allow heat currents to interfere, resulting in a thermal version of the electric Josephson interferometer. This phase-dependent mechanism of thermal transport has been the subject of much discussion, but, surprisingly, has yet to be realized experimentally. Here we investigate heat exchange between two normal metal electrodes kept at different temperatures and tunnel-coupled to each other through a thermal 'modulator' in the form of a direct-current SQUID. We find that heat transport in the system is phase dependent, in agreement with the original prediction. Our Josephson heat interferometer yields magnetic-flux-dependent temperature oscillations of up to 21 millikelvin in amplitude, and provides a flux-to-temperature transfer coefficient exceeding 60 millikelvin per flux quantum at 235 millikelvin. In addition to confirming the existence of a phase-dependent thermal current unique to Josephson junctions, our results point the way towards the phase-coherent manipulation of heat in solid-state nanocircuits.

Fractionalized excitations in the spin-liquid state of a kagome-lattice antiferromagnet

Tian-Heng Han, Joel S. Helton, Shaoyan Chu, Daniel G. Nocera, Jose A. Rodriguez-Rivera, Collin Broholm, Young S. Lee

Nature 492, 406–410 (20 December 2012)

The experimental realization of quantum spin liquids is a long-sought goal in physics, as they represent new states of matter. Quantum spin liquids cannot be described by the broken symmetries associated with conventional ground states. In fact, the interacting magnetic moments in these systems do not order, but are highly entangled with one another over long ranges. Spin liquids have a prominent role in theories describing high-transition-temperature superconductors and the topological properties of these states may have applications in quantum information. A key feature of spin liquids is that they support exotic spin excitations carrying fractional quantum numbers. However, detailed measurements of these 'fractionalized excitations' have been lacking. Here we report neutron scattering measurements on single-crystal samples of the spin-1/2 kagome-lattice antiferromagnet $ZnCu_3(OD)_6Cl_2$ (also called herbertsmithite), which provide striking evidence for this characteristic feature of spin liquids. At low temperatures, we find that the spin excitations form a continuum, in contrast to the conventional spin waves expected in ordered antiferromagnets. The observation of such a continuum is noteworthy because, so far, this signature of fractional spin excitations has been observed only in one-dimensional systems. The results also serve as a hallmark of the quantum spin-liquid state in herbertsmithite.

Exact Results for the Kondo Screening Cloud of Two Helical Liquids

Thore Posske, Chao-Xing Liu, Jan Carl Budich, and Björn Trauzettel

Phys. Rev. Lett. 110, 016602 (2013)

We analyze the screening of a magnetic quantum dot with spin 1/2 coupled to two helical liquids. Interestingly, we find two qualitatively different sets of Toulouse points, i.e., nontrivial parameters for which we can solve the two channel

Kondo model exactly. This enables us to calculate the temperature and voltage dependent Kondo screening cloud, which develops oscillations for an applied spin voltage μ_s. Such a spin voltage can be conveniently applied by a charge bias in a four-terminal helical liquid setup.

Time-Reversal Symmetry and Universal Conductance Fluctuations in a Driven Two-Level System
Simon Gustavsson, Jonas Bylander, William D. Oliver
Phys. Rev. Lett. 110, 016603 (2013)
In the presence of time-reversal symmetry, quantum interference gives strong corrections to the electric conductivity of disordered systems. The self-interference of an electron wave function traveling time-reversed paths leads to effects such as weak localization and universal conductance fluctuations. Here, we investigate the effects of broken time-reversal symmetry in a driven artificial two-level system. Using a superconducting flux qubit, we implement scattering events as multiple Landau-Zener transitions by driving the qubit periodically back and forth through an avoided crossing. Interference between different qubit trajectories gives rise to a speckle pattern in the qubit transition rate, similar to the interference patterns created when coherent light is scattered off a disordered potential. Since the scattering events are imposed by the driving protocol, we can control the time-reversal symmetry of the system by making the drive waveform symmetric or asymmetric in time. We find that the fluctuations of the transition rate exhibit a sharp peak when the drive is time symmetric, similar to universal conductance fluctuations in electronic transport through mesoscopic systems.

Fermion-Parity Anomaly of the Critical Supercurrent in the Quantum Spin-Hall Effect
C. W. J. Beenakker, D. I. Pikulin, T. Hyart, H. Schomerus, J. P. Dahlhaus
Phys. Rev. Lett. 110, 017003 (2013)
The helical edge state of a quantum spin-Hall insulator can carry a supercurrent in equilibrium between two superconducting electrodes (separation L, coherence length ξ). We calculate the maximum (critical) current I_c that can flow without dissipation along a single edge, going beyond the short-junction restriction $L \ll \xi$ of earlier work, and find a dependence on the fermion parity of the ground state when L becomes larger than ξ. Fermion-parity conservation doubles the critical current in the low-temperature, long-junction limit, while for a short junction I_c is the same with or without parity constraints. This provides a phase-insensitive, dc signature of the 4π-periodic Josephson effect.

Time Reversal Invariant Topological Superconductivity and Majorana Kramers Pairs
Fan Zhang, C. L. Kane, E. J. Mele
arXiv:1212.4232

Resilience of d-wave superconductivity to nearest-neighbor repulsion
D. Sénéchal, A. Day, V. Bouliane, A.-M. S. Tremblay
arXiv:1212.4503

Direct imaging of topological edges states with cold atoms
N. Goldman, J. Dalibard, A. Dauphin, F. Gerbier, M. Lewenstein, P. Zoller, I. B. Spielman
arXiv:1212.5093

Skyrmion Formation and Optical Spin-Hall Effect in an Expanding Coherent Cloud of Indirect Excitons
D. V. Vishnevsky, H. Flayac, A. V. Nalitov, D. D. Solnyshkov, N. A. Gippius, G. Malpuech
arXiv:1212.5485

Millisecond charge-parity fluctuations and induced decoherence in a superconducting qubit
D. Ristè, C. C. Bultink, M. J. Tiggelman, R. N. Schouten, K. W. Lehnert, L. DiCarlo
arXiv:1212.5459

Gapped phase in AA stacked bilayer graphene
L. Brey, H. A. Fertig
arXiv:1212.5363

Correlated Topological Phases and Exotic Magnetism with Ultracold Fermions
Peter P. Orth, Daniel Cocks, Stephan Rachel, Michael Buchhold, Karyn Le Hur, Walter Hofstetter
arXiv:1212.5607

Statistical Topological Insulators
I. C. Fulga, B. van Heck, J. M. Edge, A. R. Akhmerov
arXiv:1212.6191