Discovery of the Reverse Quantum Limit

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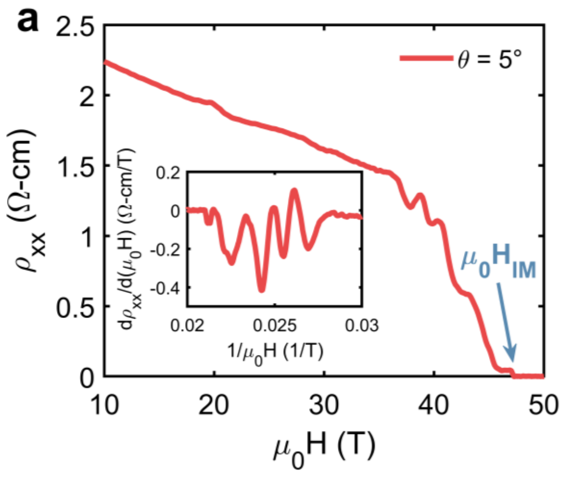
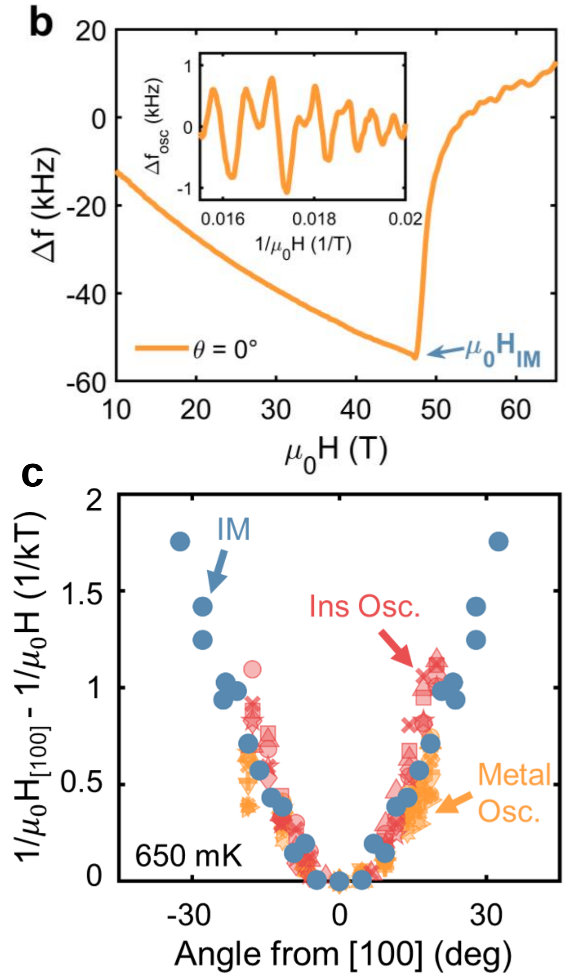
The quantum limit occurs in a Fermi liquid when a single Landau level is occupied in high magnetic fields. This highly degenerate configuration is susceptible to instabilities which can yield unconventional electronic states, especially in materials with strong electronic correlations. While most often considered in metals, a direct analogue to the quantum limit has been discovered in insulators that is characterized by Landau levels which fill in the reverse order compared to regular metals and are closely connected to a field-induced insulator-to-metal transition. This "reverse" quantum limit is shown to manifest in the Kondo insulator YbB_{12} and explain many features of its behaviour under high magnetic fields.

With quantum oscillations beginning around 35T and an insulator-metal transition extending to nearly 55T, much of the rich physics exhibited by YbB_{12} requires large magnetic fields. As such, the unique capabilities of the 65T short-pulse and 75T duplex magnet systems at the National High Magnetic Field Laboratory's Pulsed Field Facility located within Los Alamos National Laboratory were central to this work. The collaboration between internal MagLab scientists and external users combined two different measurement techniques (conventional and contactless resistivity) on ultrahigh quality single crystals down to ^{3}He temperatures in both the 65T short-pulse and 75T duplex magnet systems to reveal this exciting physics.

The discovery of the reverse quantum limit suggests that strongly-correlated insulators may be the leading candidates to realize and explore the rich array of unconventional electronic phases expected to arise in the (reverse) quantum limit. Since the reverse quantum limit can also explain many extraordinary observations in the strongly-correlated insulator YbB_{12}, it is possible the recent paradoxical observation of quantum oscillations in the insulating state of YbB_{12} may be connected to electronic instabilities associated with the quantum limit.





Quantum oscillations in the (a) insulating state and (b) field-induced metallic state of YbB_{12} single crystals were measured using conventional and contactless resistivity methods at the Pulsed Field Facility. (c) Both sets of quantum oscillations possessed the same angular dependence as the field-induced insulator-to-metal transition, a signature of the reverse quantum limit.

Facilities and instrumentation used: 65T short-pulse and 75T duplex magnets at the National High Magnetic Field Laboratory's Pulsed Field Facility.

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