High magnetic field frontiers in Superconductors, Heavy Fermions, Multiferroics, and Quantum Magnets reveal exotic states of matter

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Advances in the production of high magnetic fields with clean electromagnetic environments, and substantial progress in the electronics and experimental techniques, have now made entirely new frontiers of condensed matter (T,H) phase diagrams available and amenable to direct observation in the laboratory. Research efforts at the National High Magnetic Field Laboratory in the area of high temperature superconductors have uncovered intriguing details of their Fermi surface that suggest a condensate that lives on a corrugated magnetic landscape. The very existence of a Fermi surface in these unusual materials, questioned by some until recently, is now well established and its details scrutinized to shed new light on the superconducting pairing mechanism. Heavy fermion systems $Ce_3Pt_4In_3$, URu_2Si_2, $CeIn_3$, and YbInCu4, lent themselves to the first specific heat experiments in fields up to 60 Tesla (a million times Earth's field on the surface), giving us access to metal-insulator transitions, quantum critical points, Fermi surface reconstruction and metamagnetism, phenomena that can be fine tuned with a magnetic field knob. These results have put an enormous pressure in the theorists to properly model strongly correlated electrons, a phenomenally complex task still in early stages of development. Low dimensional and frustrated quantum magnets as well as multiferroics brought back a sense of relief and sanity to the community, since in these systems calculated phase boundary critical exponents, dimensional reduction, magnetization plateaus and spin lattice correlations can be contrasted directly with experiment. Time permitting, I will discuss some remarkable examples of the most exiting condensed matter phenomena observed by my team and close collaborators at high magnetic fields.