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Geometric Manipulation of Quantum Phase and Correlations in Nanoassembled Spin Systems[1]

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The single-impurity Kondo problem, in which an isolated magnetic impurity in a non-magnetic metallic host has its spin screened by spins of conduction electrons, has been extensively studied both theoretically and through bulk experiments. Recently new methods have allowed detailed experimental probing of the prototype single-impurity Kondo effect of individual magnetic atoms. In addition, spin interactions with confined electron states were used to materialize "quantum mirages" consisting of a nonlocal single-impurity Kondo effect. When many spin and spatial states are present in a bulk conductor or on its surface, the interactions between them may engender novel collective effects. Using a scanning tunneling microscope we assembled and studied atomically precise arrangements of (magnetic) Co atoms and (non-magnetic) CO molecules on the Cu(111) surface. The spin degeneracy of single magnetic atoms and the conduction electrons alone provide necessary ingredients for Kondo physics. When combined with quantum resonators, Kondo phase shifts can be measured by using the nanostructures as quantum interferometers. We study the effects of adding to the degeneracy of the system in two controlled ways: engineering degeneracies in the spatial states of confined electrons coupled to the spins, and engineering lattices of many spins coherently coupled through electrons. The first type of experiment has enabled a novel method to read out and geometrically manipulate the quantum phase associated with state superpositions. The second class of experiments has enabled investigation of the finite size spin physics of Kondo droplets. In these periodic structures we observe signs of quantum interference and spin correlation effects when the geometries are suitable tuned relative to the Fermi wavelength of the host electron systems. These new quantum materials act as model systems for understanding complementary physics in complex matter.

[1]Work performed in collaboration with L. S. Mattos, C. R. Moon, B. K. Foster, G. Zeltzer, and C. P. Lutz.