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Spin dynamics of atoms and magnetic nanostructures on surfaces

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Scanning tunneling microscopy is a powerful tool for studying the electronic and magnetic properties of magnetic nanostructures on surfaces. Over the last decade, inelastic tunneling spectroscopy has been used to probe discrete energy levels of quantum spin systems. These states can often be described as solutions of simple spin Hamiltonians. In spin excitation spectroscopy, a spin system is kicked from the ground into excited spin states at discrete energy increments. In this talk we will focus on the dynamics of quantum spin systems on surfaces. STM can measure tunnel currents in the range of pico amps with millisecond time resolution. This time resolution is well matched to observing transition between spin states of artificial magnetic nanostructures on surfaces that can be built and measured with STM. We will highlight an example of extended, artificial antiferromagnets on a Cu2N surface (Science 2012). Smaller magnetic clusters relax much faster but their dynamics can be measured with pump probe techniques. A pump voltage pulse drives the spin system into excited states and a subsequent probe pulse measures the resulting population of spin states. An exponential decay back to the ground state is observed when averaging over many pump-probe cycles (Science 2010). We will show results down to nanosecond time resolution with an ultimate limit set by modern electronics at about 100 pico seconds. Individual atoms on Cu2N relax their spin states even faster. Hence, another technique is employed to determine spin relaxation times: small tunnel currents always leave the spin system in the ground state while high currents can create non-equilibrium distributions of spin states. This approach relies on some modeling but allows time domain measurements down to about 1 pico second (Nature Physics 2010). Transition metal atoms on metal surfaces relax even faster, on time scales of about 100 femtoseconds. This fast relaxation manifests itself as a measurable lifetime broadening of spin excitation spectra. Combining these approaches allows measurements of spin relaxation times over about 16 orders of magnitude for spins on surfaces – while maintaining the atomic scale spatial resolution of STM!