Research Direction	Conceptual description	Our contributions
Coherent spin manipulation of electrons on helium	Electrons confined on the surface of liquid helium interact almost exclusively with each other, and with the electrostatic potential of underlying gates. A precise hamiltonian can be "dialed in" by tuning a set of gate voltges, combining the purity of atomic physics with the control of a condensed matter system.	With our experience measuring the spin states of gate-confined electrons in semiconductors as a springboard, we will use GaAs quantum point contacts as an electrometer to investigate the entangled spin states of coupled electrons on liquid Helium
Scalable coupling of quantum circuit elements in GaAs	Over the last 15 years GaAs/AlGaAs heterostructures have provided the most successful platform for realizing "designer" hamiltonians because of the low defect density and large degree of control available in that system. Recently it has become possible to control those hamiltonians down to the single electron level. New paradigms are needed, however, for measuring circuits of more than two of these few-electron elements coupled together.	The difficulty of coupling multiple few-electron devices together comes from the fact that the typical Fermi wavelength in a GaAs 2D electron gas is somewhat smaller than the smallest feature size that can be lithographically defined. Although two few-electron elements can be coupled together, extending beyond two has proven difficult. We will investigate new device geometries that may get around this problem.
Harnessing nuclear spin on a local scale	The success of MRI as a biological research tool is rooted in the pristine quantum coherence of nuclear spin, even at ambient conditions and room temperature. This coherence persists due to weak interactions between nuclear spin and the environment. By taking advantage of the hyperfine interaction with conduction electrons, however, it is possible to design devices that will allow control over both the electron and nuclear spin degrees of freedom.	Preliminary work has demonstrated the complex dynamics of the coupled electron-nuclear system in GaAs nanostructures. Fluctuations of an uncontrolled nuclear spin bath present a significant barrier to quantum control over electron spin in these materials. When the electron-nuclear dynamics is understood, however, experimental data provides strong indications that the hyperfine coupling will allow for detection and control of the local nuclear spin environment.
Topological Qubits in the Fractional Quantum Hall Regime	This is a topic the falls midway between "designer hamiltonians" and devices based on new quantum properties. Like many other qubit strategies in GaAs, topological quantum information is stored in degrees of freedom directly related to device geometry. At the same time, those degrees of freedom arise directly out of an exotic bulk property of the two-dimensional electron gas that can emerge in a perpendicular magnetic field.	It has been proposed that edge states of the nu=5/2 Landau level have a non-abelian topological character. We will attempt to measure this characteristic for the first time. Following two theoretical proposals from last year, we will then attempt to measure quantum information stored in the edge state occupation of a so-called antidot in a GaAs 2D electron gas.
Mesoscopics in strongly correlated systems	Many of the most important questions in condensed matter physics arise in systems with strong electron-electron interactions. Such systems often give rise to exotic quantum phases with surprising collective properties. But until now, there have been few examples of devices that incorporate these new quantum properties at a microscopic level.	In the past decade, experiments in 2D systems with strong interactions have uncovered surprising metal-insulator transitions, including evidence for a spontaneous spin polarization at low density. Many of the questions raised by these experiments are difficult to address in a bulk measurement. Mesoscopic devices fabricated from these materials will provide a powerful new tool to study these strongly-correlated 2D systems.
Transport in Single Molecules	Single molecules represent the extreme example of nanostructured quantum materials. And yet, a molecule selected based on certain characteristics or synthesized by chemists is not far from the perfect designer hamiltonian. Single molecule measurements are quintessential examples of both ends of the spectrum covered in this proposal.	In biggest impediment to reliable single molecule transport measurements is accurately characterizing the contacts between molecules and bulk leads. Before moving on to the many exciting theoretical proposals for single molecule measurements, we will work to develop a reliable technique for contacting single molecuels electrically.