BOSTON UNIVERSITY

Quantum Condensed Matter Theory

We are a cohesive group that uses an array of theoretical methods to address relevant experimental problems in condensed matter physics.

Group Members

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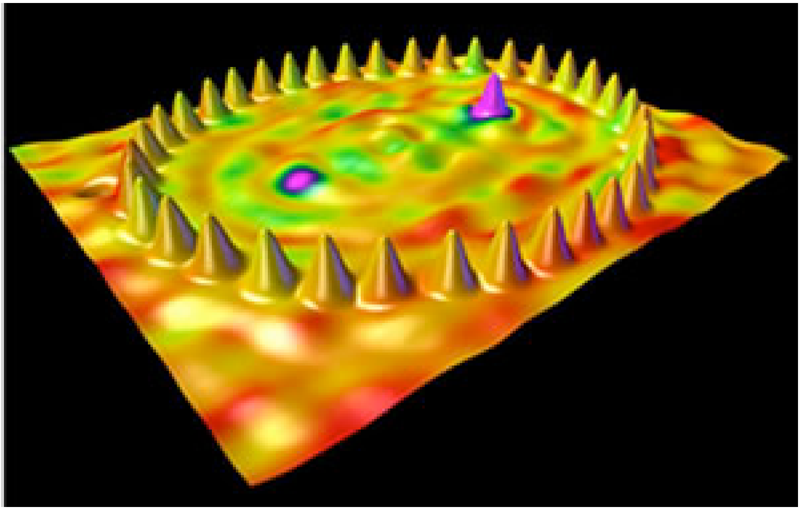
3 post-docs, 10 students, 7 visiting scientists/yr

Quantum Impurity Problems

Many problems in condensed matter physics reduce to a single quantum mechanical degree of freedom interacting with a reservoir. These are among the simplest problems which exhibit non-trivial many-body effects that can be studied in a well-controlled way.

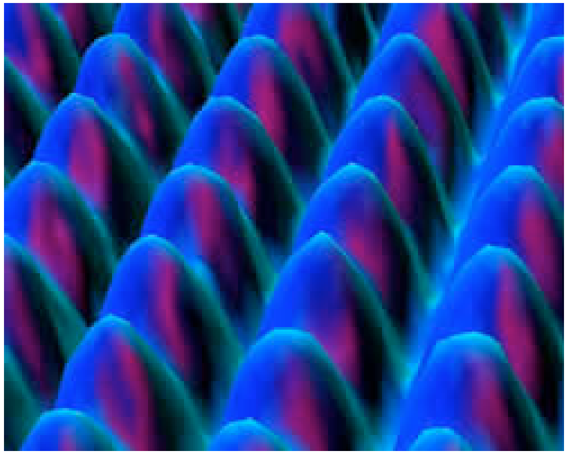


Scanning Tunneling Microscope (STM) image of a Co atom in a Quantum Corral

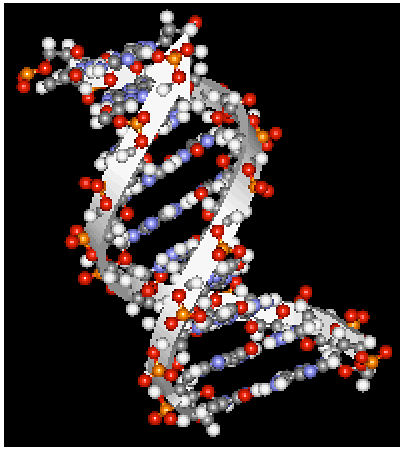
- Kondo effect and dissipative two-level system
- Magnetic impurities in magnetic systems
- Quantum brownian motion
- Qubit decoherence
- Tunneling between quantum Hall edge states

Low Dimensional Systems

Quantum fluctuation effects are stronger in lower dimensions invalidating standard approximations such as mean-field theories and leading to surprising new effects. New techniques borrowed from quantum field theory can be used very effectively in this area.



STM image of a Ni surface

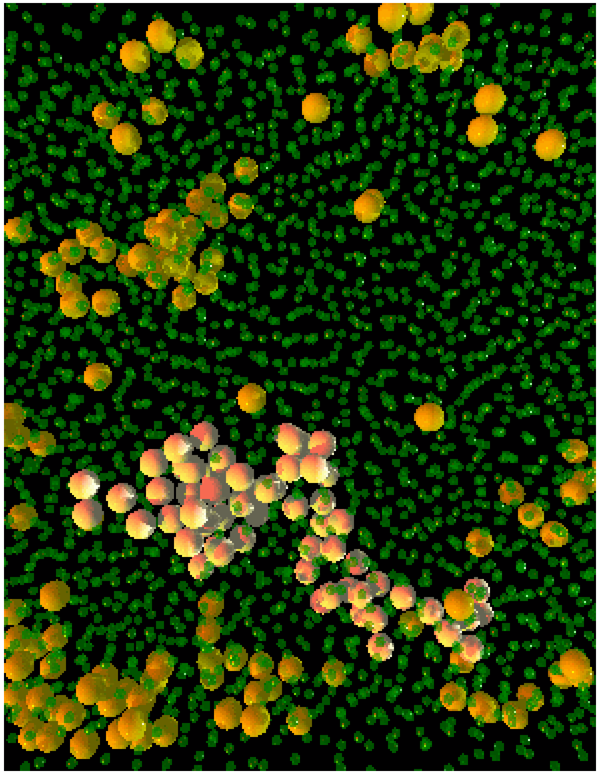


DNA molecule

- Quantum Spin Chains
- Kondo Chain
- Two-Dimensional Antiferromagnets
- Two-Dimensional Charge Density Wave System
- Frustrated antiferromagnets
- Electronic Transport in DNA

Disordered Eletronic and Magnetic Systems

Real materials always contain defects that crucially affect their properties. Interpretation of experimental data usually requires the understanding of how these defects interact with the quantum and classical degrees of freedom.



Colloidal glass

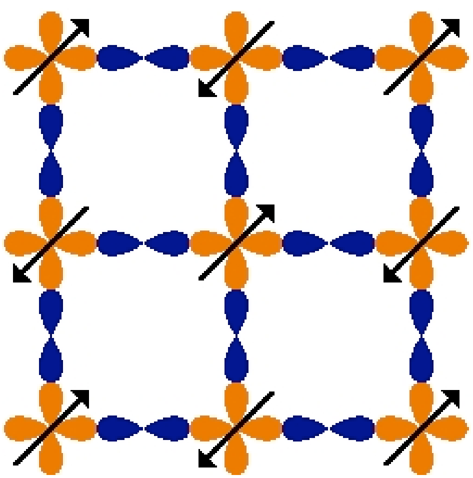
- Disorder and Interacting electrons in two dimensions
- Two-Dimensional disordered Antiferromagnets
- Non-equilibrium dynamics in glasses
- Random non-magnetic impurities in magnets
- Griffiths phases of U and Ce intermetallics

Superconductivity

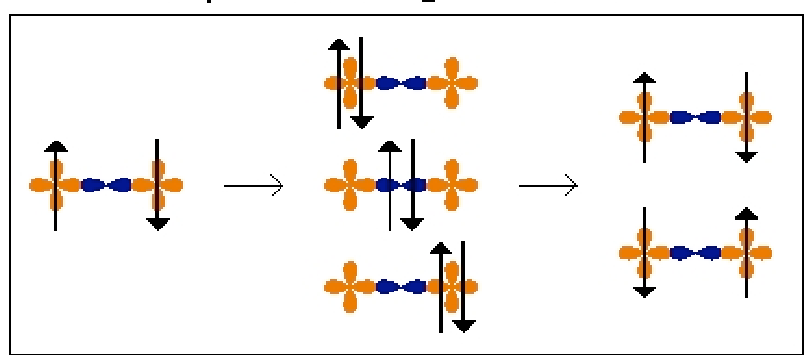
This fascinating macroscopic quantum mechanical effect occurs in some electronic systems at sufficiently low temperatures when 10^{23} electrons move together in perfect harmony. High temperature superconductivity is one of the most important open problems in modern condensed matter physics.

Floating Magnet on a HTc Material

- High-Tc theory
- Liquid crystal vortex matter
- Vortex Lattices in d-wave superconductors
- Josephson tunneling in Luttinger liquids
- Impurities in d-wave superconductors

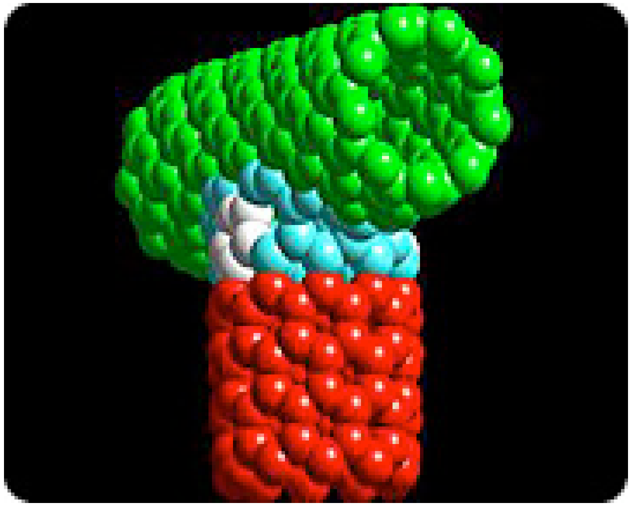


superexchange mechanism

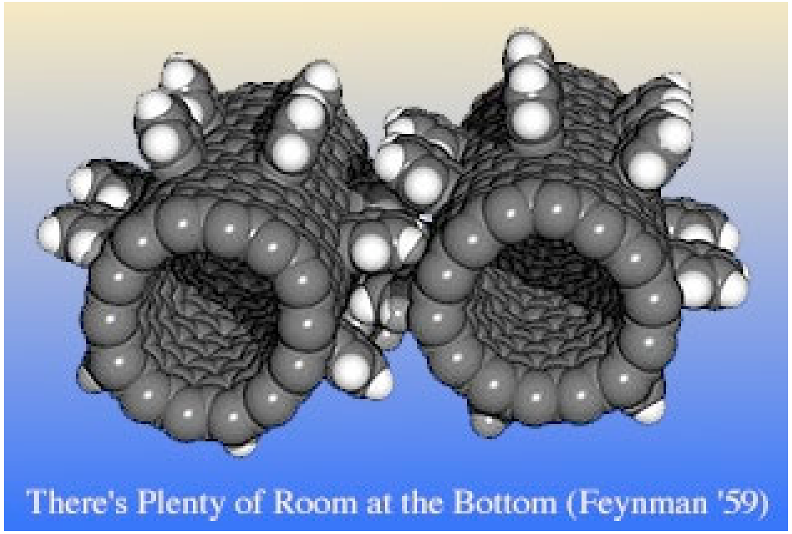


Nano-scale Physics and Spintronics

As electronic devices become smaller and smaller, quantum mechanical effects become important. Understanding these effects in nano-scale structures can open the doors for futuristic devices including quantum computers.



Nano-junction



Nano-engines

- Strongly correlated effects in nano-structures (such as nanotubes)
- Kondo Effect in Quantum Dots
- Spin pumping
- Magnetically doped semiconductors

Methods

We use a variety of theoretical methods, some of them borrowed from high energy physics and string theory (conformal field theory, topological field theories), large scale numerical simulations, renormalization group, and path integral techniques.