Probing Hidden Order and Magnetic Disorder in Correlated Electron Systems Using Spin Probes, DMR-0203524

The term "hidden order" has been coined in the literature to convey the lack of understanding regarding the nature of a new state of electronic matter in the compound URu_2Si_2. The new state is achieved by this material at temperatures below 17 degrees Kelvin (-256 ^{o}C). The material also undergoes a superconducting transition at even lower temperatures (-272 ^{o}C). The superconducting state is very unconventional and likely related to the hidden order.

Our nuclear magnetic resonance (NMR) work is shedding light on this very interesting area of condensed matter physics. We interact with groups from the USA, Japan, and Europe.

The pictures at right show the PI with some of the students who have worked on this project. Those currently enrolled are listed in the caption.

Condensed Matter NMR at California State University Los Angeles:

* PI
* 2 undergrads
  Odet Bonilla
  Fred Warnecke
* 1 grad (MS):
  Mike Moroz

At California State University LA the Pi and his students have performed NMR experiments in two of the nuclear isotopes available in URu_2Si_2: ^{29}Si and ^{99}Ru. The crystal structure of this material is characterized by two features: a principal axis "c" and a basal plane "a-b". Because the position of ^{29}Si and ^{99}Ru is different within a single cell of the crystal structure, the two isotopes actually probe the magnetic field at different environments allowing one to map the local configuration of the internal magnetism. We have found that the internal field at the Si sites is isotropic, but that the internal field at the Ru sites is not. The symmetry of the field at the Ru sites is such that the in-plane component is about twice as large as that one along the principal c-axis of the crystal. This is the first time that planar (a-b) anisotropy is observed in the properties of URu_2Si_2. It is an important result because the magnetism of this system has been always considered to have Ising symmetry; meaning that the internal fields are strong along the main crystal axis only. We have found the first evidence that the hidden order might have symmetry other than Ising. Since the theory behind the hidden order requires the knowledge of the internal field symmetry, we can expect that our measurements will impose constraints that can be used to develop the correct model for hidden order. Theorists from Rutgers University have already developed a model of "orbital antiferromagnetism" to explain some of these observations, and continue to use our most recent results to fine tune their predictions and propose further experiments. We have, so far, published three papers addressing these issues in the following journals: Physical Review Letters, Physica B, and Journal of Magnetism and Magnetic Materials. Understanding the nature of this hidden order might open the doors to new and unexpected technological applications as well as innovative methods of control and device design.

Probing Hidden Order and Magnetic Disorder in Correlated Electron Systems Using Spin Probes, DMR-0203524

Our work has opened new questions for further experimentation at Cal State LA and elsewhere.

At top right is a picture of a small (2/10" wide) single crystal sample of URu_2Si_2 mounted on a special probe. The probe was developed at the National High Magnetic Field Lab in Tallahassee, Florida, by a group of scientists collaborating with the PI. It allows one to study the material at a continuous range of orientations with respect to an applied magnetic field (*H*). By characterizing the sample's response for different orientations, one expects to learn about the properties of the hidden order state at low temperatures.

The figure at right represents the NMR spectra above (red) and below (blue) the hidden order temperature obtained at an angle of 90 degrees. The effects of hidden order are therefore detectable using this technique.