Quasiparticle Behavior in Bose Quantum Liquids

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Quasiparticles carry energy in condensed matter. In the world of quasiparticle physics, understanding when and how these energy carriers fail opens doors to another level of understanding, and can lead the way to many new and important theories. Scientists at the U. S. Department of Energy's Brookhaven National Laboratory have discovered the failure point for the quasiparticle construct, the standard model of condensed matter physics. This could have far-reaching implications, for example, in the study of high-temperature superconductors, materials currently under intense scrutiny as a possible replacement for the conventional superconducting materials now used in many facets of everyday life.

At the March 2005 meeting of the American Physical Society, Brookhaven physicist Igor Zaliznyak will explain how he and his colleagues identified the "spectrum endpoint" in a Bose quantum spin liquid, the point at which the quasiparticles are no longer well-defined energy carriers. Zaliznyak will discuss his paper at 1:39 p.m. Friday, March 25, 2005, in Room 515B of the Los Angeles Convention Center.

"Although the quantum-liquid state has been studied for roughly a century, it continues to fascinate physicists," Zaliznyak said. "We have demonstrated that at higher energies, the Bose quasiparticle description fails because of quasiparticle decay."

The study of quasiparticles, which govern the properties of quantum liquids, was pioneered by Russian Nobel Prize winning-physicist L.D. Landau. There are two types of quasiparticles, Bose and Fermi, and physicists around the globe are exploring the properties of each type. The Brookhaven experiments, conducted using the triple-axis neutron spectrometer at the National Institutes of Standards and Technology, confirmed that in a particular Bose quantum spin liquid, quasiparticle decay leads to spectrum termination, as was predicted by Landau.

“Landau proposed that at some energy, the quasiparticle description breaks down, and in a generic form this has been known,” Zaliznyak said. “But the extent of the phenomenon and how it reveals itself in real materials hasn’t been clear. We have shown that at twice the minimum excitation energy, known as the spin gap, Bose quasiparticles cease to be defined at all and disappear.”

The Brookhaven experiments studied a quantum liquid found in systems composed of quantum spins in magnetic crystals, specifically an organo-metallic material known as PHCC. The scientists’ neutron scattering measurements demonstrate the occurrence of spectrum termination in the two-dimensional quantum spin liquid found in PHCC.

“When you attempt to create an excitation that is more than twice the gap rate, it’s possible that your excitation decays, “ Zaliznyak said. “In Bose quantum liquids, when decay processes like this become allowed, you can’t have quasiparticles.”

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