

Inelastic Neutron Scattering Studies of Strongly Correlated Electron Systems

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1. Introduction

The inelastic neutron scattering technique with its unparalleled energy and momentum coverage suits best for investigations of the dynamics of various kinds of materials. Moreover, that neutrons have no charge and so penetrate deep into the sample allows one to probe the bulk properties without undesirable effects due to the surface, which often poses problems to other techniques.

Over the last two decades or so, the inelastic neutron scattering has produced some very important results in the research area of strongly correlated electron systems such as heavy fermion and high temperature superconductors to name only a few. Information gleaned from such inelastic neutron scattering experiments is very crucial for further microscopic understanding of a given system.

In this paper, we will give a few examples where we used the inelastic neutron scattering technique to examine the dynamical susceptibility.

2. Experimental Details

For the works presented here, we used several inelastic neutron scattering instruments. Two particular instruments are employed more often than any others. One is the High Energy Transfer spectrometer (HET) of ISIS, Rutherford Appleton Laboratory, UK, and the other is the chopper spectrometer IN6 of Institut Laue Langevin, France. All our data were converted into absolute units using data taken from a standard V sample.

3. Results and Analysis

In this section we present some of our recent works. The topics covered here include the spin dynamics of multiferroic hexagonal manganites, crystal field excitations of heavy fermion compounds, the spin dynamics of systems near quantum critical points, and systems with spin gap.

3.1 Dynamics and Structure of Hexagonal Manganites[1-3]

Hexagonal manganites belong to a class of so-called multiferroic materials. Most hexagonal manganites exhibit ferroelectric transitions at around 900 K and antiferromagnetic transitions below 100 K. That it has both transitions of different nature in a single compound opens up a possibility that one may be able to control one order parameter by varying another. Such

a possibility in fact has been experimentally demonstrated in some recent pioneering works. In this work, we have concentrate on the spin dynamics as well as structural studies of several systems: YMnO_3 , LuMnO_3 , and ErMnO_3 . We will discuss our experimental results in terms of a model Hamiltonian and a scenario invoking spin-lattice coupling.

3.2 Crystal Field Excitations: URu_2Si_2 , CeNiSn , and CeRhSb [4,5]

When localized f electrons are introduced to solids with different charge environments, their degenerate ground states are split into several levels. How they are split depends critically on the surrounding charge configurations. This splitting of the degenerate ground states is a so-called crystal field level splitting. Here, we show some examples where inelastic neutron scattering was employed to determine the crystal field scheme and demonstrate how this information was used to further understand the physical properties.

3.3 Quantum Critical Points[6,7]

There are numerous examples in nature showing phase transitions. Although the underlying mechanism of such phase transitions is undoubtedly driven by quantum mechanics, their dynamics is usually governed by thermal fluctuations, which is basically of classical nature. However, there have been several reports of examples whose dynamics is governed not by such thermal fluctuations but by so-called quantum fluctuations. Here, we will give key characteristics of the spin dynamics of such examples measured by the inelastic neutron scattering technique.

3.4 Systems with Spin Gap[8]

When there is strong correlation effect among electrons, both charge and spin sectors of the dynamics are strongly modified by such correlation effects. One consequence of such effects is a so-called spin gap formation. The inelastic neutron scattering technique is the only experimental method that allows to measure the momentum dependence of such a spin gap. Here we will give some examples with spin gap.

4. Conclusion

In this paper, we have shown several examples, where the inelastic neutron scattering technique produces very useful information. It is needless to say

that there are other enormous areas of research fields, which I have not covered here.

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