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Theoretical Study of Electron Phonon Interaction in Heavy Fermion Systems

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Abstract – A systematic theory of the electron-phonon interaction in heavy-fermion systems is created based on the mean-field approximation for the Kondo lattice. The electron-phonon interaction is brought into the Anderson Hamiltonian by expecting that the hybridization between f electrons and conduction electrons relies upon the local lattice strain. The interaction with conduction electrons is incorporated by utilizing a distortion potential-type coupling. By illuminating the mean-field conditions within the sight of lattice displacements, interactions depicted by Kondo bosons are remembered for the current theory. Utilizing an irregular phase-type approximation for the Kondo-boson propagators, the phonon self-energy and the flexible constants are determined. The interaction mediated by phonons is inferred, and its opposition with the interaction by Kondo bosons is considered. The aftereffects of the current theory are contrasted and a powerful static electron-phonon interaction. It is discovered that this is a reasonable approximation for interaction measures with enormous momentum move and little frequencies The expanding of this difference by temperature makes the movement of the f electrons hybrid from wave proliferation to dissemination. This mechanism clarifies the noticed double nature of the f electrons, to be specific that at low temperatures they carry on like a Fermi fluid, while at high temperatures they develop into a grid of limited magnetic minutes.

Keywords – Heavy-Fermion Systems, Interaction, Conduction Electrons

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INTRODUCTION

Heavy Fermion System

The disclosure and investigation of the properties of some inter metallic mixes containing uncommon earth and Actinide components in the only remaining century have upset both in the theory and analyses of strong state material science. These mixes at an incredibly low temperature structure a highly connected electron states which display many interesting inconsistencies of electronic, attractive and lattice properties. It is accepted that the peculiar property appeared in these systems are because of the solid hybridization of related electron states with that of the conduction band close to the Fermi level. Besides, under a trademark temperature T*, these systems show Fermi fluid conduct with enormous viable mass m, that is the reason these systems are likewise alluded as heavy fermion systems (HFS).

The investigation of these rare earth and Actinide mixes began for all intents and purposes around 1950 with the advancement of new technology to isolate different rare earth elements. From the outset they were treated as an average case of nuclear like localized attraction because of very much localized 4fstates, all around screened by the 5s and 5p filled orbitals. In light of the huge radial repulsion with l = 3 for the f-shell, the 4f orbital is empty while the 6s, 5p and 5d shells are filled.

The elements beginning from Lanthanum (nuclear number Z = 57) and finishing at Lutetium (nuclear number (Z = 71)) are known as the Lanthanides and beginning from Actinium (nuclear number Z = 89) and finishing at Lawrencium(atomic number Z = 103)are known as Actinides are rare earths and are described by the reformist filling of their 4f and 5f shell individually. Scandium (Z = 21) and Ytterbium (Z = 39) are likewise remembered for the class of rare earth due to their comparable actual properties. Rare earth shapes an assortment of intermetallic mixes and compounds with change metal and metalloid. Trial examination on these intermetallic mixes and amalgams in the past have uncovered that a portion of the mixes containing Ce, Eu and Yb and scarcely any different elements in that gathering display interesting actual properties related with the electrons, for example, attractive requesting with strangely high temperature, Kondo impact superconductivity heavy fermion (HF) conduct and blended valence or valence change conduct

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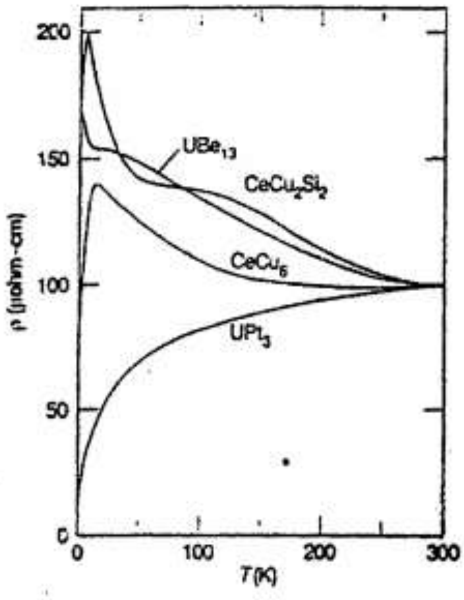

Figure 1.: The resistivity versus temperature for several heavy-electron compounds displaying a range of behaviours.

The magnetic susceptibility adheres to a Curie-Weiss law where Curie-Weiss temperature is negative. Fig 1 shows the variety of susceptibility (χ) with temperature which observe Curie- At low temperature the conduct of susceptibility isn't exceptional and saturates at a consistent and very improved worth The Curie like high temperature susceptibility saturates under a change temperature T* in an upgraded Pauli type susceptibility trademark for a non-magnetic Fermi fluid ground state.

Heavy Fermion Superconductors

Heavy fermions systems are the systems that contain certain uncommon earth (overwhelmingly Ce) or actinide (dominatingly U) particles and that have surprising low temperature properties. These mixes at amazingly low temperature structure an exceptionally related electron state, which show many fascinating irregularities of electronic, magnetic and grid properties. It is likewise accepted that the strange property appeared in these systems are because of solid hybridization of associated/electron states with that of conduction band close to Fermi level. Under a trademark temperature T, which is of the request several Kelvin, these systems carry on like Fermi fluids with enormous viable mass m which is as extensive as two or three hundred times the free electron mass.

Superconducting heavy fermions systems have pulled in extraordinary interest since they are considered as potential possibility for whimsical blending. The actual system answerable for superconductivity is an appealing interaction between electrons that outcomes from a virtual trade of local second fluctuations, instead of the trading of phonons that prompts superconductivity in common metals. They are the primary known superconductors with matching due not to phonon trade yet because of electron interactions. Heavy fermion superconductivity has been given a lot of consideration as far as thoughts non BCS conduct brought about by the magnetic variance. A whimsical superconductor is decisively one that breaks a balance of the precious stone point bunch other than the standard worldwide evenness broken by a superfluid or superconductor. It regularly suggests that the request parameter and in this way additionally the superconducting hole disappears at some evenness plane. This arrangement of the superconducting ground state as per its balance bunch gets from the overall landau theory of second request phase progress yet was explicitly evolved on account of superconductivity for heavy fermion systems and they are 3D superconductors with a lot bigger assortment conceivable superconducting ground state. The conceivable unpredictable superconductivity in heavy fermion systems ought to be portrayed by the presence on the Fermi surface of focuses on lines with evaporating superconducting hole prompting power law temperature conditions underneath Tc of excitation subordinate actual properties.

In a heavy electron metals, the turn circle coupling is huge and it ought to be remembered for the investigation from the earliest starting point. All these heavy electron superconductors take shape in structures with focuses of reversal balance. It follows that at each pair of (k, ~k) focuses there are four savage Bloch states which change into one another under the evenness activities of reversal and time inversion Another interesting part of heavy fermion superconductivity is that seems to coincide with some sort of static attraction happening above. The tale part of heavy fermion superconductors is that both the semi molecule shaping the cooper combines just as the electrons conveying the attraction above have verifiably the equivalent/characters. The most intriguing part of heavy fermion material science remains the perception of superconductivity originally recognized in This disclosure comprise an achievement in the investigation of superconductivity. The framework was the principal U-based heavy fermion superconductor found. It shows impossible to miss properties highlighting an unpredictable superconducting request parameter. The particular warmth underneath Tc = 0.86K observes near a law with the presence of focuses on the Fermi surface with disappearing superconducting hole.

The hexagonal heavy fermions superconductor has showed up as the heavy fermion superconductor. Explicit warmth examines shows the presence of two superconducting phase transitions in zero outer field interpreted as phases with various request parameter. In an outer field one watches a multicomponent graph with in any event three superconducting phases meeting at a tetra basic point Explicit warmth contemplates uncovered the presence of two superconducting phase transitions in zero outer fields. Besides, in an outer magnetic field, one watch a multi-part chart with at any rate three superconducting phases meeting at a point. The incident between the two superconducting progress temperature and the temperature comparing to the expansion of the depolarisation rate are appeared in

Fig. 2. Heavy fermion superconductors UPd_2Al_3 and UNi_2Al_3

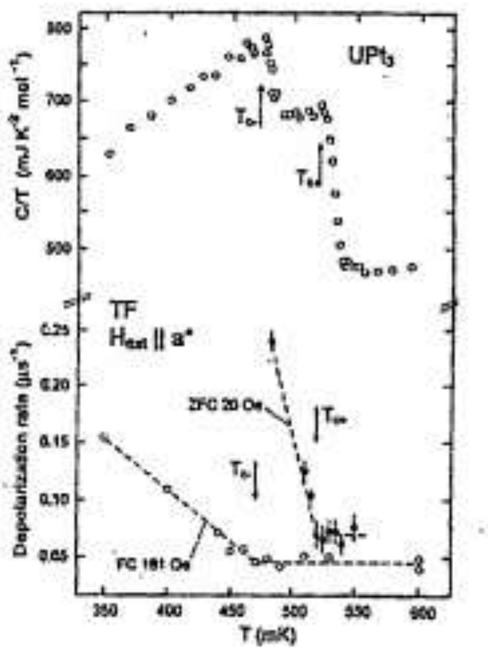

Figure 2: Temperature dependence of the Gaussian transverse field n+ depolarization rate in UPt3 obtained in field-cooling (FC) and zero-field-cooling (ZFC) procedures in a high-quality singly crystal

Kondo Lattice

One class which is much of the time referenced regarding heavy fermion systems is basic metals containing weaken centralization of magnetic pollutants. The actual properties of these systems are effectively depicted by the Kondo model in which a d-level or f-level of the debasement has an energy just underneath the Fermi level. Since the beginning of metal material science it has been entrenched test certainty that a few pollutants with an unfilled 3d-shell have all around characterized magnetic second when broken up in basic metal, for example, copper where others are non-magnetic . A striking marvel the opposition least was additionally found long back and its association with the magnetic pollution has been stressed. This obstruction least marvel is very not the same as superconductivity in which a sharp drop of protection from zero is watched.

The systematic investigation of weaken composites of 3d elements in basic host anyway began distinctly around 1950s when the outcomes of magnetic minutes in metals became explained by tests which adds up to be a local properties of compounds. Magnetic and non-magnetic debasement states were first represented by Friedel and Anderson the Hartree-Fock arrangement of the proposed model lead to a reasonable differentiation among magnetic and non-magnetic states. The clarification of the obstruction least by Kondo in 1964 began a tremendous movement in this field. The opposition least signals the beginning of a smooth change to a non-magnetic state at low temperature. Consequently exploratory and hypothetical endeavors focused on the idea of this progress. Properties well underneath the trademark temperatures called the Kondo temperature were immovably settled later. The force law conduct temperature found by extremely cautious tests are currently interpreted by Fermi fluid theory.

Mixed Valence Compounds

Mixed valent or fluctuating valent systems are those which have blended or fluctuating valence. The term blended valency previously came into strong state material science, to our knowledge concerning aggravates like explored by Jonker and Van Santen . These mixes have the intriguing property that the delocalization of electrons is joined by ferromagnetic requesting.

Anderson Model

The Anderson model is a procedure pertinent for an arrangement of conduction electrons that interact with a local turn. The change conditions of Schrieffer and Wolff shows that the Anderson model has a few terms that are like the Kondo model. The Kondo model depicted an arrangement of conduction electrons interacting with a separately localized turn . The local turn can have any estimation of rakish momentum S, and the conduction electrons can be treated in one, a few measurements. Early labourers imagined that the two models made fundamentally the same as forecasts. Presently it is realized that the Anderson model has a more prominent assortment of conduct. It has the all the more interesting material science. It can go through trade and different cycles with the conduction electrons. This model treats the local turn as simply one more electron. Most utilizations of the Anderson model think about the localized state to have turn and orbital decline.

Huge numbers utilizations of the Anderson model have been for heavy fermion systems, where the local orbital is a f - electron.

The Kondo model treats the local turn as a different substance. The Anderson model treats local turn as a different element. Treatment of weaken magnetic composites community on two models, related to the names of Anderson, Kondo and Cobbling and Schrieffer. The more crucial model is the Anderson model. Anderson concocted a basic however

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nontrivial model for a pollution in a metal that had the ability of building up a magnetic second. Thusly it worked out that the conduction band of the metal could screen out the pollutant second at low temperature. The three elements of this model are

(i) Conduction band with energy scattering e(k),

(ii) Contamination iota able to do twofold inhabitancy with a solitary orbital energy 6f and Coulomb relationship energy U related with twofold inhabitancy of the orbital, and

(iii) Hybridization grid component 14 that couples the orbital level with the leading states.

This model portrayed the interaction of delocalized conduction electrons with a highly localized magnetic pollution. Contamination electrons are unequivocally associated by the presence of an on location coulomb repulsion U and blend pitifully in with conduction states through a hybridization grid component

The Hamiltonian may be written as

$$H_A = H_{\text{band}} + H_{\text{imp}} + H_{\text{mix}} \tag{1.1}$$

$$H_{\text{band}} = \sum_{k,\sigma} \epsilon_{k,\sigma} n_{k,\sigma} \tag{1.2}$$

$$H_{\text{imp}} = E_\sigma n_\sigma + U n_{k\uparrow} n_{k\downarrow} \tag{1.3}$$

$$H_{\text{mix}} = \sum_{k,\sigma} \left(V_{kf} (c^\dagger_{k,\sigma} f_{k\sigma}) + V_{fk} f^\dagger_{k,\sigma} c_{k,\sigma} \right) \tag{1.4}$$

Here $\epsilon_{k\sigma}$ denotes the energy of the conduction electrons, with creation operator $(c^\dagger_{k,\sigma})$ $E_\sigma \rightarrow$ Energy of the impurity state and annihilation operators $c_{k,\sigma}$.

Periodic Anderson Model

The Periodic Anderson Model has end up being an exceptionally integral asset in the examination of many interesting wonders which portray change metal and rare earth mixes. Among them we review Kondo impact, blended valence, chemisorptions, heavy fermions Even however the model isn't actually feasible, pertinent outcomes have been gotten by implies of suitable approximation plans . Anderson Model examined the issue of a solitary magnetic pollution in a metal which additionally consider the local type of coulomb interaction. Occasional Anderson Model is a speculation of one pollution instance of Anderson model . So in PAM lattice is inserted in the ocean of conduction electron. The Periodic Anderson model comprises of two subsystem, an arrangement of uncorrelated conduction electrons moving in a generally expansive band and an intermittent cluster of localized f-electrons which are unequivocally connected. There is a hybridization interaction which encourages the change of electrons between the localized and the extended states and is liable for the intermediate valence.

The Hamiltonian for such a system of interacting electron is given by

$$H = \sum_{k,\sigma} \epsilon_{k,\sigma} c^\dagger_{k,\sigma} c_{k,\sigma} + \sum_{i,\sigma} E_\sigma f^\dagger_{i,\sigma} f_{i,\sigma} + U \sum_i n^f_{i,\uparrow} n^f_{i,\downarrow} + \frac{1}{\sqrt{N}} \sum_{k,i,\sigma} \{ V_k e^{ik \cdot R_i} c^\dagger_{k,\sigma} f_{i\sigma} + H.c \} \tag{1.5}$$

This model has wide scope of immaterialness to depict change metals, alloys, blended valence compound, HF framework and Kondo insulators. The coulomb interaction between two electrons is U.

OBJECTIVES OF THE STUDY

1. To Study on properties of associated electronic systems which are basically constrained by the coulomb interaction between the electrons and their quantum trade. In these systems the potential energy of electrons is more than the decline energy related with the trade in fermions.

2. To study on A systematic theory of the electron-phonon interaction in heavy-fermion systems is created based on the mean-field approximation for the Kondo lattice.

CONCLUSION

In this current theory an endeavour has been made to clarify the current phonon inconsistencies in some HF systems. These are the intermetallic mixes of a portion of the rare earth and actinide gathering of elements and structures a highly corresponded electron systems at low temperature. From various trial perceptions, it is seen that there exists a nearby likeness between blended valent, Kondo and Heavy Fermions systems. This similarity is the quality of hybridization between localized f electrons and conduction electrons, intrusive coulomb repulsion of 4f electrons and the situation off level. Moreover HF system lies intermediate to extraordinary gathering of MV and Kondo systems. Therefore we quickly evaluated of HF systems as well as about MV and Kondo systems. Emphatically corresponded fermion systems are described by a solid Coulomb interaction between the electrons. The actual properties of associated electronic systems are basically constrained by the coulomb interaction between the electrons and their quantum trade. In these systems the potential energy of electrons is more than the decline energy related with the trade in fermions. In firmly associated electron systems there exist two trademark segments of electrons. The vagrant part and the Fermi level which is identified with the vehicle properties and including the superconductivity the localized character of electrons, for example, heavy fermions and High Tc cuprates.We have taken the least difficult instance of a non degenerate d orbital which has at the most twofold inhabitancy with a turn f and a turn 4-electron. U is the local coulomb relationship in d state and speaks to the quality of hybridization among conduction and f electrons. The conduction band is treated by a generally structure less thickness of states - typically a steady with a limited band width. For any contamination iota that really builds up a magnetic second in a metal, it has turned out that a bunch of savage orbitals are included: 3d orbitals for change metals. 4f for rare earth and 5f for Actinides. The interaction between the f level and the conduction band is treated as steady, autonomous of the azimuthal quantum number at the f orbital electron wave number and energy.

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