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The role of many-particle intermediate states in the formation of the Abrikosov-Suhl resonance

P. Fazekas and A. Zawadowski

HUNGARIAN ACADEMY OF SCIENCES
CENTRAL RESEARCH INSTITUTE FOR PHYSICS

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The role of many particle intermediate states in the formation of the Abrikosov-Suhl resonance

P.Fazekas and A.Zawadowski

Central Research Institute for Physics, Budapest, Hungary

Recently many attempts [1-3] have been made to derive the expression of the electron scattering amplitude for the Abrikosov-Suhl resonance. There are essential similarities and equivalences among the different approaches applied to this problem [4]: e.g. diagram method [1], S-matrix theory [2] and decoupling the Green's function equations [3]. The basic formulas of the second and third approaches can be derived using Abrikosov's diagram technique considering only the one electron /hole/ intermediate states.

The dynamics of the impurity spin has been investigated by the authors [5, 6] making use of the pseudofermion representation [1] of the spin operators $\vec{S} \to a^+_\alpha \vec{S}_{\alpha\beta} a_\beta$.
It has been found that the real part of the pseudofermion self-energy for $|\omega| \ll kT$ is

$$Re\Sigma_{pseudo,\alpha\alpha'}(\omega) = -\left\{ S(S+1)(\omega\delta_{\alpha\alpha'} - S^z_{\alpha\alpha'}\omega_0) + \omega_0 S^z_{\alpha\alpha'} \right\} \gamma(T) \tag{1}$$

where ω_0 is the resonance frequency of the free spin in the presence of external magnetic field,

$$\gamma(T) = \frac{1}{2}\left(2\frac{J}{N}\rho_0\right)^2 \log\frac{D}{kT}\left(1 + 2\frac{J}{N}\rho_0 \log\frac{D}{kT}\right)^{-1}$$

$\frac{J}{N}$ is the exchange coupling constant in the Kondo Hamiltonian, D is the cut-off energy. In the neighbourhood of its pole, the pseudofermion Green's function can be written as

$$G_{pseudo,\alpha\alpha'}(\omega) = \delta_{\alpha\alpha'} \frac{Z(T)}{\omega - \omega_0 S^z_{\alpha\alpha'}\frac{g_{ren}}{g_0} - \omega_K S^z_{\alpha\alpha'} - \lambda} \tag{2}$$

where $Z(T)=\{1+S(S+1)\gamma(T)\}^{-1}$ is a renormalizátion constant λ is the pseudofermion energy, ω_K is the Knight shift and the ratio of the renormalized and free impurity gyromagnetic factor is $\frac{g_{ren}(T)}{g_0}=1-\left(\frac{1}{Z(T)}-1\right)\frac{1}{S(S+1)}$
These calculations have been performed in logarithmic approximation, which is satisfactory if $0,8\lesssim Z, \frac{g_{ren}}{g_0}\lesssim 1$ i.e. well above the Kondo temperature.
It can be seen that the renormalization constant decreases as the spincompensated state forms /also g_{ren} decreases/. The appearance of the renormalization constant may be taken into account by the renormalization of the exchange coupling constant $J_{ren}/T/=JZ/T/$, for the bare vertex is connected to two pseudofermion lines. The slight temperature dependence of $J_{ren}/T/$ leads to an essential change in the temperature dependence of the scattering amplitude. E.g. the characteristic Kondo energy E_0 is modified according to the following ratio

$$\frac{E_0(J_{ren}(T))}{E_0(J)}=\frac{\exp\left\{\frac{N}{2J_{ren}(T)\rho_0}\right\}}{\exp\left\{\frac{N}{2J\rho_0}\right\}}=\exp\left\{\frac{N}{2J\rho_0}S(S+1)\left(1-\frac{g_{ren}}{g_0}\right)\right\}$$

In the case $\frac{2J\rho_0}{N}\sim 10^{-1}-10^{-2}$ this change in the characteristic Kondo energy may be of a few order of magnitudes even in that temperature region where [1-2] are valid and which is determined from $0,8<\frac{g_{ren}}{g_0}<1$.

In the pseudofermion self-energy /1/ only one electron-hole pair has been considered as intermediate states /Fig.1/.Inserting this correction into the electron self-energy, the diagram shown in Fig.2. is obtained where the intermediate states are one electron /hole/ + one electron-hole pair.$^{+}$
Therefore, the corrections given here have been neglected in the previous works [1-3], [7].

One can conclude that the many particle intermediate states play important role in the Abrikosov-Suhl resonance, in spite of the fact that only a class of the electron self-energy diagrams has been considered in this way. As the many particle intermediate states have been neglected in the earlier theories e.g. Ref.7. we can not expect good agreement between experiments and theories for the measurable quantities /resistivity, susceptibility/ even above the Kondo temperature.

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Footnote $^{+}$ The pseudofermions are not mentioned here.

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Figure Captions

1. Pseudofermion self-energy.

2. Correction to the electron self-energy with three particles (electron, hole) intermediate states.

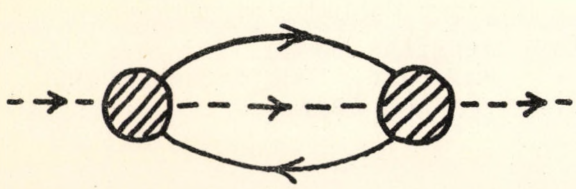

Fig. 1.

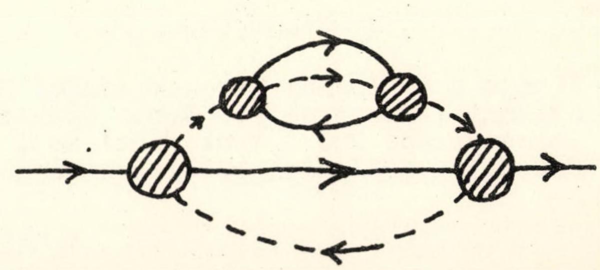

Fig. 2.

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