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Semi-fermionic approach for quantum spin systems

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Outline

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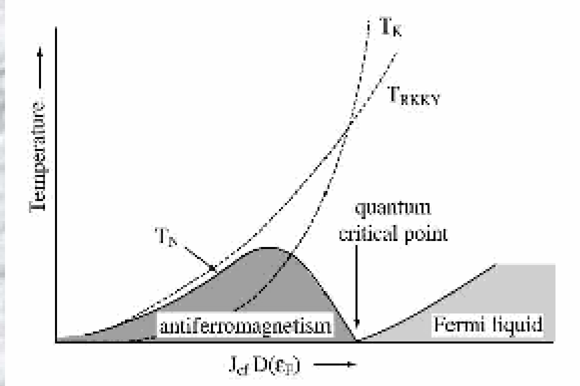

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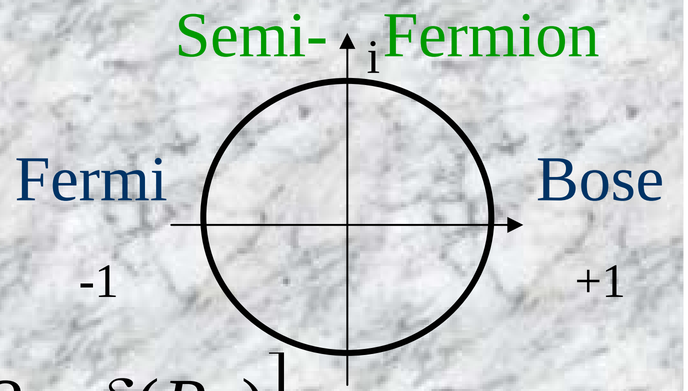
Model

$$H = \sum_k \varepsilon(k) c^+_{k,\sigma} c_{k,\sigma} + J \sum_i \vec{S}_i \vec{s}_i + \sum_{ij} I_{ij} \vec{S}_i \vec{S}_j$$

d-electrons — Kondo — RKKY

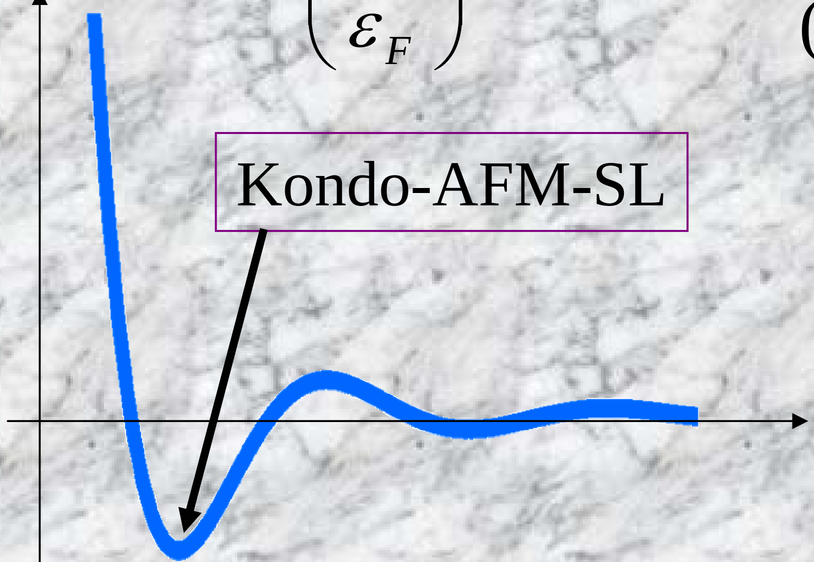
$$\vec{s} = \frac{1}{2} c^+_\alpha \vec{\sigma}_{\alpha\beta} c_\beta$$

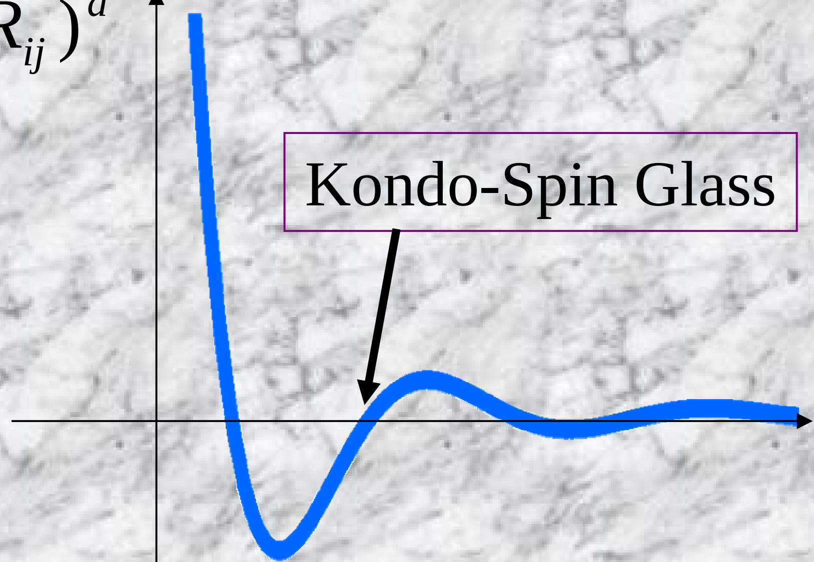
$$\vec{S} = f^+_\alpha \vec{\tau}_{\alpha\beta} f_\beta$$



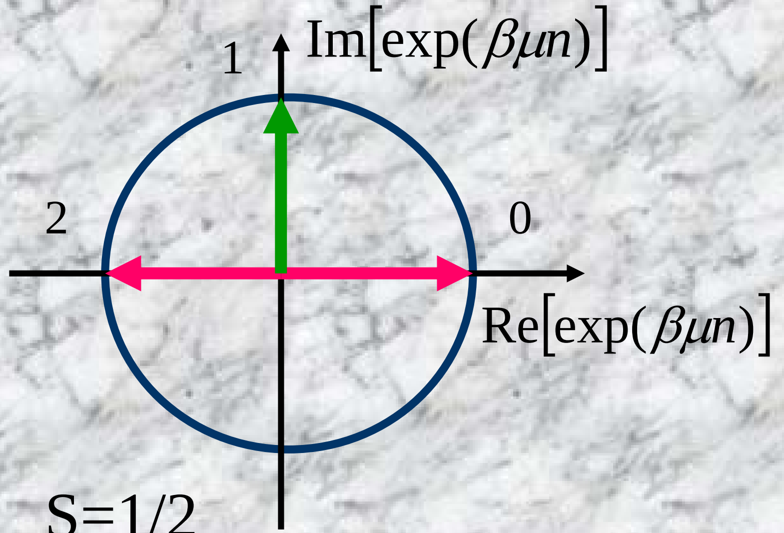
$$S^2 = S(S+1) \Leftrightarrow \sum_\alpha f^+_\alpha f_\alpha = 1$$

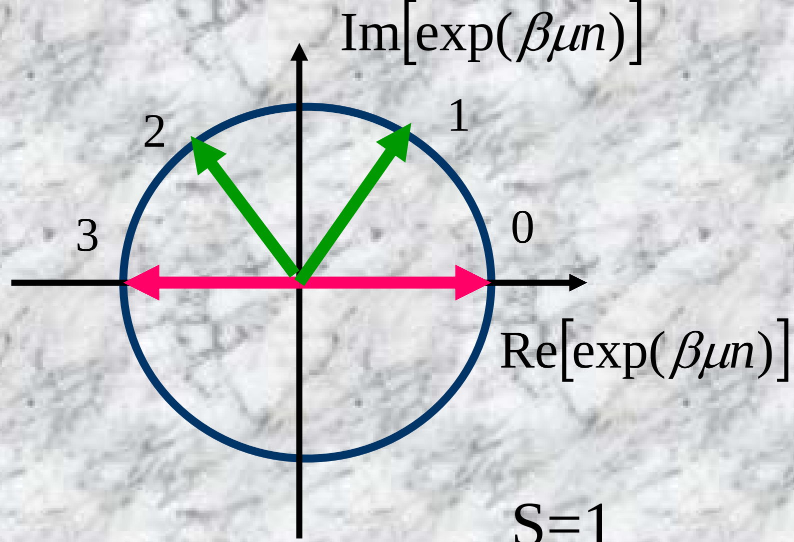
$$I_{ij} = I^{RKKY} = -\left(\frac{J^2}{\varepsilon_F}\right) \frac{\cos\left[2k_F R_{ij} - \pi(d+1)/2 + \delta(R_{ij})\right]}{(2k_F R_{ij})^d}$$





Semi-fermionic representation





S=1/2

S=1

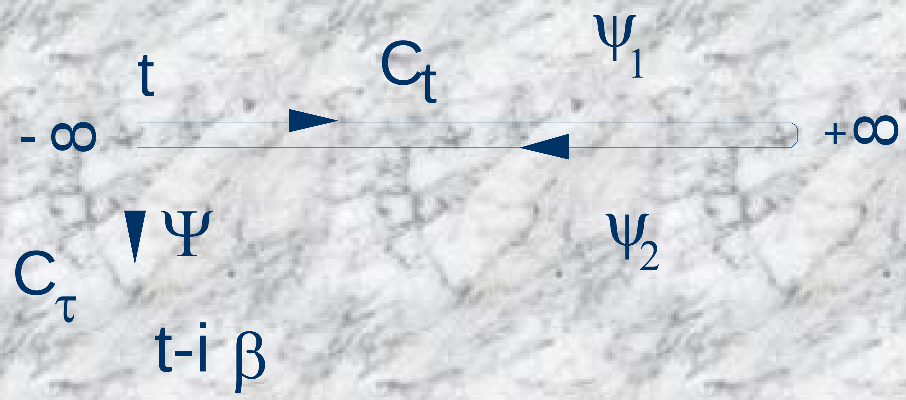
$$\omega = 2\pi T\left(n + 1/4\right)$$

$$\omega = 2\pi T\left(n + 1/3\right)$$

$$\mu = -i\frac{\pi T}{2S+1}$$

$$Z_S = Tr\left[\exp\left(-\beta H_S\right)\right] = A Tr\left[\exp\left(-\beta H_F + \beta\mu N_F\right)\right]$$

$$n^S(\varepsilon) = \frac{1}{\exp\left(i\pi/(2S+1)\right)\exp\left(\varepsilon/T\right)+1}$$



RESULTS

Kondo → AFM, SL, SG

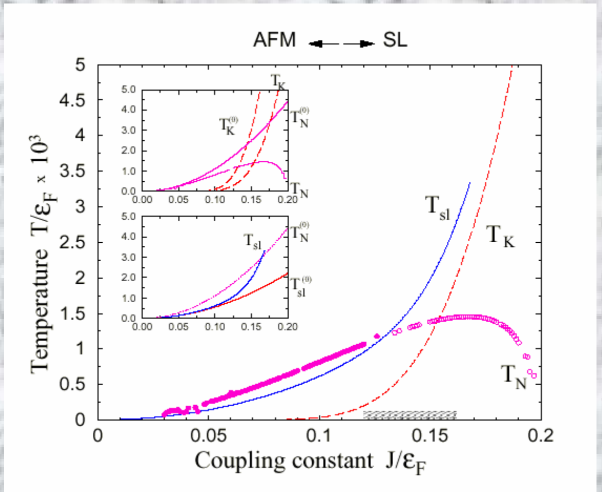
$$A=\sum_{q,n}\left[\frac{1}{J}-\Pi(N,\Delta,q,\tilde{q})\right]\left|\phi(q)\right|^2-Tr\frac{1}{J_Q}N_QN_{-Q}-Tr\frac{1}{J_{p-k}}\Delta_p\Delta_k$$

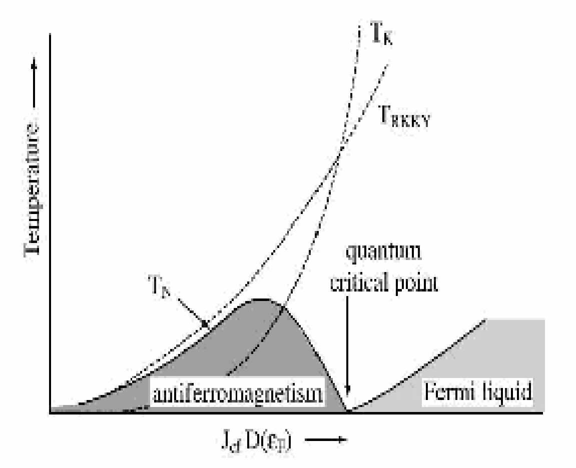
$$N=\tanh\left(\frac{I_QN}{2T}\right)\left[1-\frac{a_N}{\ln(T/T_K)}\frac{\cosh^2\left(I_QN/2T\right)}{\cosh^2\left(I_QN/T\right)}\right]$$

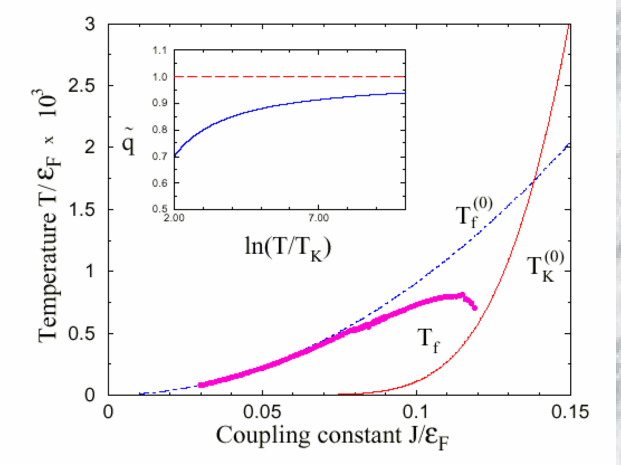
$$q=1-\frac{c_{sg}}{\ln(T/T_K)}$$

$$\Delta=\sum_q\nu(q)\left[\tanh\left(\frac{I_q\Delta}{T}\right)+a_{sl}\frac{I_q\Delta}{T\ln(T/T_K)}\right]$$

$$\tilde{q}=\int_z^G\tanh^2\left(\frac{Iz\sqrt{q}/T}{1+2c_{sg}(I/T)^2(\tilde{q}-q)/\ln(T/T_K)}\right)$$







Conclusions

- **Effective action of KL model is written in three-mode representation: Kondo-screening, AFM (SG) and spin-liquid correlations. The problem of local constraint is resolved by means of semi-fermionic representation of the localized spins.**
- **It is shown that the Kondo-screening enhances the tendency of a spin-liquid crossover and partially suppresses AFM and SG orderings.**
- **Competition between local (Kondo) and non-local (magnetic) correlations may result in appearance of Quantum Critical Point.**

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