Quantum Criticality of Kondo Lattice Model:
A Renormalization Group Study via Quantum non-Linear Sigma Model

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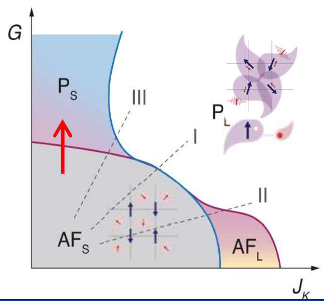
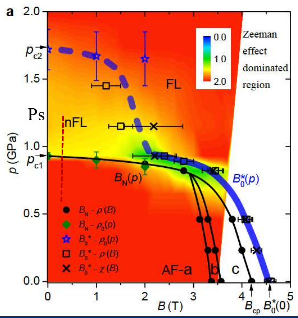
I. Motivation

- Heavy fermion metals: canonical systems for the competition between local moments & conduction electrons
- Recent experiment on CePdAl, a heavy fermion metal with distorted Kagome lattice calls for an understanding of the AF to Ps transition and the interplay between spin frustration and Kondo interaction.

H.Zhao et al., Nature Physics, 2019





II. Field Theory of Frustrated Kondo Lattice

QNLSM with Kondo coupling:

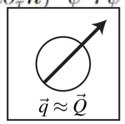
$$S = S_c + S_n + S_K$$

$$S_c = \sum_{k,\Omega} \psi^\dagger(-i\Omega + E_k)\psi \qquad c^2 \sim J_1 - 2J_2 - 4J_3$$

$$S_n = \frac{1}{2g}\int d^d x d\tau \left[(\partial_\tau n)^2 + c^2(\nabla n)^2 + (\nabla^2 n)^2\right]$$

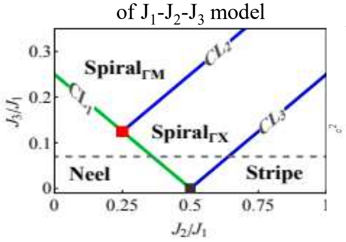
$$S_K = \lambda_K \int_{x,\tau} \sum_\alpha \partial_\alpha n \cdot \psi^\dagger \tau \psi - \frac{\lambda_K \sqrt{d}}{c_0}\int_{x,\tau} (n \times i\partial_\tau n)\cdot \psi^\dagger \tau \psi$$

Only consider Q >$2k_F$, i.e. no hot spot.

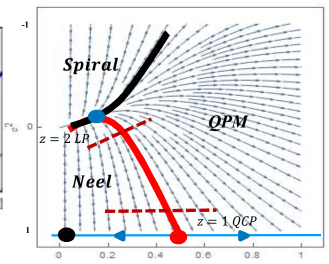


II.1 Phase Diagram of QNLSM

Classical Phase Diagram of J_1-J_2-J_3 model



RG flow of QNLSM

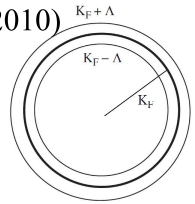


Two different universality classes for different critical points: z=1 QCP and z=2 Lifshitz point.

II.2 RG with Fermi Surface

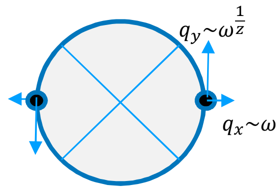
Shankar Scaling

- Fermion scaling dimension $[\psi] = -\frac{3}{2}$ (Shankar, RMP, 1994)
- Valid when boson and fermion dynamics are consistent ($z = 1$)(S. Yamamoto and Q. Si PRB 2010)



Patch Scaling

- Only same and opposite patches interact.
- Boson field is strongly coupled with FS at $q \sim |\omega|^{\frac{1}{z}}$ along tangential directions of FS for $z > 1$



II.3 RG of the QNLSM with Kondo Coupling

- At AFM and QCP (Shankar Scaling),

$$\beta(g) = -\epsilon g + g^2 \qquad \beta(\lambda) = -\frac{1}{2}(\epsilon + g)\lambda - \lambda^3$$

Stable Small Fermi Surface across QCP:

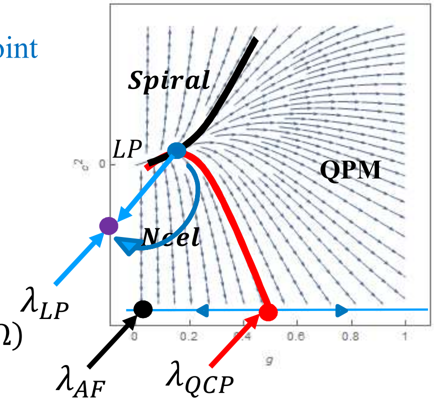
$$\Sigma(k_F, \Omega) \sim i|\Omega|^{d+\eta} sgn(\Omega)$$

- At the Lifshitz point (Patch Scaling),

$$\beta(\lambda) = \epsilon\lambda - \lambda^3$$

The Kondo Coupling flows to a non-Fermi liquid fixed point,

$$\Sigma(k_F, \Omega) \sim i|\Omega|^{\frac{2}{3}} sgn(\Omega)$$



III. Summary

- At AFM and QCP, Kondo coupling is irrelevant and the FS remains small across the QCP
- At the Lifshitz point, relevant Kondo coupling flows to a NFL fixed point (LP=NFL).
- Provide the theoretical basis for AFM to P_S transition and frustrated Kondo lattice.