Quantum criticality in a Kondo-Mott Lattice Model

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I. IMPURITY MODEL

$$H_{\text{aux}}(\mathbf{r}_d) = H_f^{(0)} + H_f(\mathbf{r}_d) + H_c^{(0)} + H_c(\mathbf{r}_d) + H_{fc}(\mathbf{r}_d)\ , \tag{1}$$

where

$$\begin{aligned}
H_f^{(0)} =& - t_f \sum_{\langle i,j \rangle, \sigma} \left(f^\dagger_{i,\sigma} f_{j,\sigma} + \text{h.c.}\right)\ ,\\
H_c^{(0)} =& - t \sum_{\langle i,j \rangle, \sigma} \left(c^\dagger_{i,\sigma} c_{j,\sigma} + \text{h.c.}\right)\ ,\\
H_f(\mathbf{r}_d) =& V_f \sum_{Z \in \text{NN}} \sum_\sigma \left(f^\dagger_{\mathbf{r}_d,\sigma} f_{Z,\sigma} + \text{h.c.}\right) - \frac{U_f}{2} \left(f^\dagger_{\mathbf{r}_d,\uparrow} f_{\mathbf{r}_d,\uparrow} - f^\dagger_{\mathbf{r}_d,\downarrow} f_{\mathbf{r}_d,\downarrow}\right)^2 \\
&+ J_f \sum_{Z \in \text{NN}} \sum_{\alpha,\beta} \mathbf{S}_f(\mathbf{r}_d) \cdot \boldsymbol{\sigma}_{\alpha\beta} f^\dagger_{Z,\alpha} f_{Z,\beta} - \frac{W_f}{2} \sum_{Z \in \text{NN}} \left(f^\dagger_{Z,\uparrow} f_{Z,\uparrow} - f^\dagger_{Z,\downarrow} f_{Z,\downarrow}\right)^2\ ,\\
H_c(\mathbf{r}_d) =& - \frac{W}{2} \left(c^\dagger_{\mathbf{r}_d,\uparrow} c_{\mathbf{r}_d,\uparrow} - c^\dagger_{\mathbf{r}_d,\downarrow} c_{\mathbf{r}_d,\downarrow}\right)^2\ ,\\
H_{fc}(\mathbf{r}_d) =& J \sum_{\alpha,\beta} \mathbf{S}_f(\mathbf{r}_d) \cdot \boldsymbol{\sigma}_{\alpha\beta} c^\dagger_{\mathbf{r}_d,\alpha} c_{\mathbf{r}_d,\beta} + V \left(f^\dagger_{\mathbf{r}_d,\sigma} c_{\mathbf{r}_d,\sigma} + \text{h.c.}\right)\ ,
\end{aligned} \tag{2}$$

II. TILING RECONSTRUCTION

$$\begin{aligned}
H_{\text{tiled}} =& \sum_{\mathbf{r}_d} H_{\text{aux}}(\mathbf{r}_d) - (N-1)\left[H_f^{(0)} + H_f^{(0)}\right]\\
=& - t_f \sum_{\langle i,j \rangle, \sigma} \left(f^\dagger_{i,\sigma} f_{j,\sigma} + \text{h.c.}\right) - t \sum_{\langle i,j \rangle, \sigma} \left(c^\dagger_{i,\sigma} c_{j,\sigma} + \text{h.c.}\right) + \tilde{J} \sum_{\langle i,j \rangle} \mathbf{S}_f(i) \cdot \mathbf{S}_{\mathbf{f}}(j) + J \sum_i \mathbf{S}_f(i) \cdot \mathbf{S}_c(i)\\
& - U \sum_i \left(f^\dagger_{i,\uparrow} f_{i,\uparrow} - f^\dagger_{i,\downarrow} f_{i,\downarrow}\right)^2
\end{aligned} \tag{3}$$