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Chasing d-wave superconductivity in the $2D$ Hubbard Model

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1 INTRODUCTION

In this report we show our DMF^{2}RG results for the $2d$ one band Hubbard model in the intermediate-to-strong coupling regime and with a Fermi surface structure similar to the cuprate one. The report is structured as follows. First we explain the cutoff choice that we have implemented. Then we show our results, namely:

- With full frequency dependence vertex we manage to recover the DMFT Néel temperature, at weak and strong coupling;
- The leading instability is incommensurate antiferromagetic;
- At strong coupling the incommensurability vector does not necessarily correspond to the one of the particle-hole bubble;
- Nonlocal fluctuations only slightly decrease the DMFT-Néel temperature;
- We do not find a d-wave pairing instability at the temperature studied;
- The d-wave pairing fluctuations can become large close to the antiferromagnetic instability, showing that the spin-fermion mechanism is active also at strong coupling.

In the second part of this report, we discuss several ideas and proposals that aim to a better understanding of the data obtained thus far.

2 METHOD AND CUTOFF CHOICE

We used a *local conserving cutoff*, which means that the Λ dependence of the Green's function is chosen in such a way that the DMFT self-consistency condition is verified for every Λ-value:

$$\int_{\mathbf{k}} G^{\Lambda}_{\mathbf{k},\nu}|_{\Sigma^{\mathrm{DMFT}}} = \mathcal{G}_{\nu}. \tag{2.1}$$

Here $\mathcal{G}_{\nu}$ is the Green's function of the Anderson Impurity model associated with the DMFT problem of the lattice system considered. The notation $|_{\Sigma^{\mathrm{DMFT}}}$ means that the Green's function is computed with the DMFT self-energy $\Sigma^{\mathrm{DMFT}}_{\nu}$, see below. The Λ-dependent Green's function is defined by:

$$G^{\Lambda}_{\mathbf{k},\nu} = \left[i\nu + (1-\Lambda)\epsilon_{\mathbf{k}} + \mu - f^{\Lambda}_{\nu} + \Delta_{\nu} - \Sigma^{\Lambda}_{\mathbf{k},\nu} \right]^{-1}, \tag{2.2}$$

where Δ_{ν} is the hybridization function associated to the Anderson Impurity model, $\mathcal{G}_{\nu} = \left[i\nu - \Delta_{\nu} + \mu \right]^{-1}$. The function f^{Λ}_{ν} is fixed to guarantee equation 2.1. Considering that G and $\mathcal{G}$ fulfill the DMFT self-consistency condition one has $f^{\Lambda=1}_{\nu} = 1$, $f^{\Lambda=0}_{\nu} = 0$.

3 RESULTS

3.1 HALF FILLING AT STRONG COUPLING

- Flow at strong coupling: flow of the magnetic channel+flow of the susceptibility;
- The Néel temperature can be extrapolated from the inverse of the susceptibility. While the Néel temperature is strongly reduced by the local fluctuations including nonlocal fluctuations and self-energy feedback does not reduce the temperature much further, at least in the half-filling, particle-hole symmetric case of Fig. 3.2. Away from half-filling where also other channels come into play, the nonlocal channel competition is slightly more effective, but we never find a complete suppression of incommensurate antiferromagnetism to ascribe to nonlocal fluctuations in other channels.
- Magnetic channel frequency plot, at strong and weak coupling;

3.2 AWAY FROM HALF FILLING

- doping scan at fixed temperature $\beta = 50$: Critical scale and pairing fluctuations;
- flow of the d-wave channel (at different temperatures?);
- Perpendicular ladder, comparison of the d-wave in different schemes: PL, decoupled, dmf2rg;

4 PROPOSED INVESTIGATIONS

- origin of d-wave superconductivity;

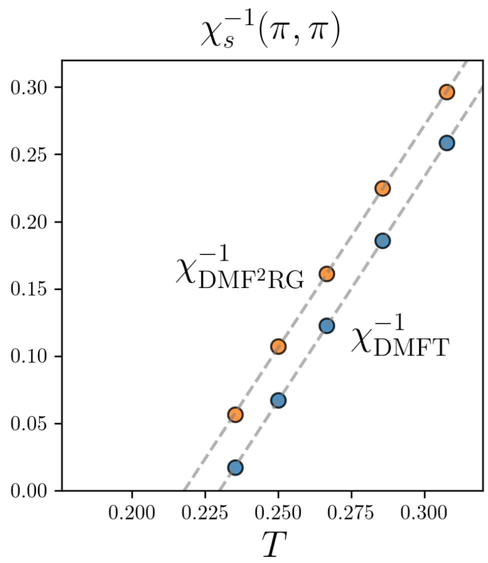

Figure 3.1: Extrapolation of the susceptibility for $U = 4t$ and in the particle-hole symmetric case.

5 Rawdata and plots to get

- flow of susceptibility+flow of the magetic (strong coupling HF); **Demetrio**
- Extrapolation of Néel temperature from susceptibility (with self-energy);**Ciro**
- Magnetic channel frequency plot, at strong and weak coupling; **Ciro+Demetrio script**
- doping scan at fixed temperature $\beta = 50$: Critical scale and pairing fluctuations; **Ciro**
- flow of the d-wave channel (at different temperatures?); **Demetrio**
- Perpendicular ladder→ comparison of the d-wave in different schemes: PL, decoupled, dmf2rg (function of Λ also for the Magnetic) **Demetrio**;
- Maximum of d-wave as function of the maximum of $\mathcal{M}$;
- Decoupled vs non decoupled (AF+d-wave fluct) Phase diagram **Ciro** - plot of the maximum of the d-wave as function of the maximum of the magnetic in two different ways. a) fixed doping, b various dopings (final Λ) ;

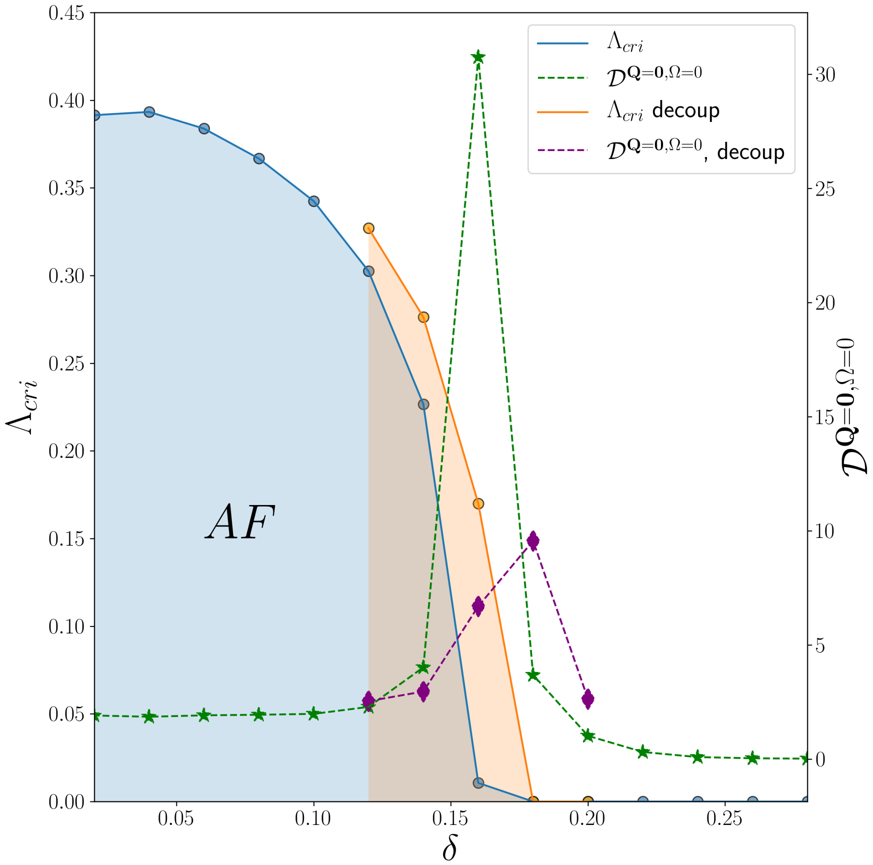

Figure 3.2: Extrapolation of the susceptibility for $U = 4t$ and in the particle-hole symmetric case.

6 Ideas and proposal (easy or in progress)

- Fermi Surface at strong coupling: Is the Fermi surface prone to have hot spots, also in the presence of a relatively large self-energy? How is this important for the superconductivity.

7 Further studies (hard or to be planned)

- d-wave fluctuations beyond the critical scale: how to get them?