

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

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## 1 INTRODUCTION

In this report we show our DMF<sup>2</sup>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 antiferromagnetic;
- 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  $\Lambda$  dependence of the Green's function is chosen in such a way that the DMFT self-consistency condition is verified for every  $\Lambda$ -value:

$$\int_{\mathbf{k}} G_{\mathbf{k},\nu}^{\Lambda} |_{\Sigma^{\text{DMFT}}} = \mathcal{G}_{\nu}. \quad (2.1)$$

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  $|_{\Sigma^{\text{DMFT}}}$  means that the Green's function is computed with the DMFT self-energy  $\Sigma_{\nu}^{\text{DMFT}}$ , see below. The  $\Lambda$ -dependent Green's function is defined by:

$$G_{\mathbf{k},\nu}^{\Lambda} = \left[ i\nu + (1 - \Lambda)\epsilon_{\mathbf{k}} + \mu - f_{\nu}^{\Lambda} + \Delta_{\nu} - \Sigma_{\mathbf{k},\nu}^{\Lambda} \right]^{-1}, \quad (2.2)$$

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

## 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 susceptibility.
- 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, dmft2rg;

## 4 PROPOSED INVESTIGATIONS

- origin of  $d$ -wave superconductivity;

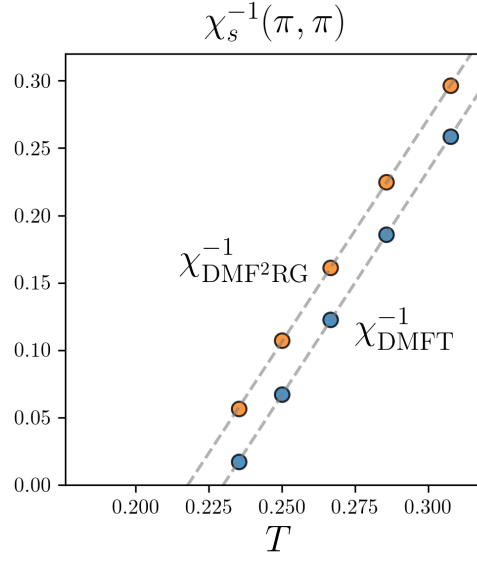


Figure 3.1: Extrapolation of the susceptibility for  $U = 4t$  and in the particle-hole symmetric case.

## 5 RAWDATA AND PLOTS TO GET

- flow of susceptibility+flow of the magnetic (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, dmft2rg (function of  $\Lambda$  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  $\Lambda$ ) ;

## 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?