Excitons and spins in strongly correlated systems

Louk Rademaker, Driebergen 9 March 2010

Universiteit Leiden
The Netherlands

Overview

- Excitons in Mott insulators

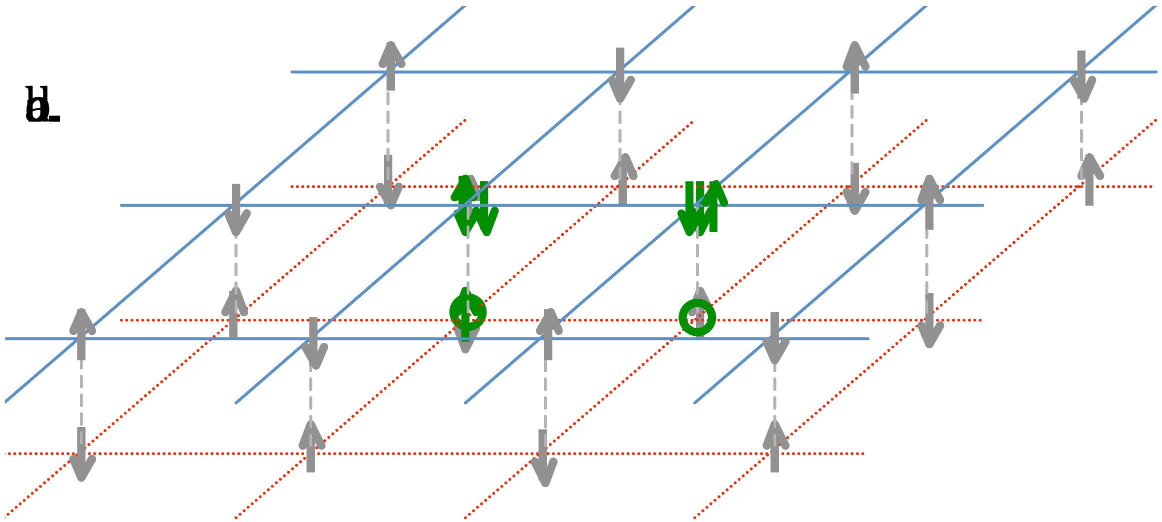
- Bilayer Heisenberg Spin Wave theory

- Results

Excitons in Mott insulators

- What are Mott insulators?

- Interlayer excitons



Interlayer excitons

- Spin (magnetic) background

$$H = J \sum_{<ij>} (S_{1,i} \cdot S_{1,j} + S_{2,i} \cdot S_{2,j}) + J_\perp \sum_i S_{1,i} \cdot S_{2,i}$$

- Exciton motion term

$$H_{t,e} = -\frac{t^2}{V} \sum_{<ij>\sigma\sigma'} e_j^\dagger \left[c_{in\sigma'}^\dagger c_{ip\sigma}^\dagger c_{jp\sigma} c_{jn\sigma'} \right] e_i$$

- Pretty awful…

Linear Spin Wave theory

- Mean field ground state

$$H = J \sum_{<ij>} S_i \cdot S_j$$

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- Local spin excitations

$$\begin{aligned} S_i^+ &= a_i \\ S_i^- &= a_i^\dagger \\ S_i^z &= \frac{1}{2} - a_i^\dagger a_i \end{aligned}$$

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- Only consider ‘linear’ terms (no interactions)

$$H = -\frac{1}{8} N J z + \frac{1}{2} J z \sum_i \hat{n}_i + \frac{1}{2} J \sum_{<ij>} (a_i b_j + a_i^\dagger b_j^\dagger)$$

- Diagonalize using Fourier & Bogoliubov

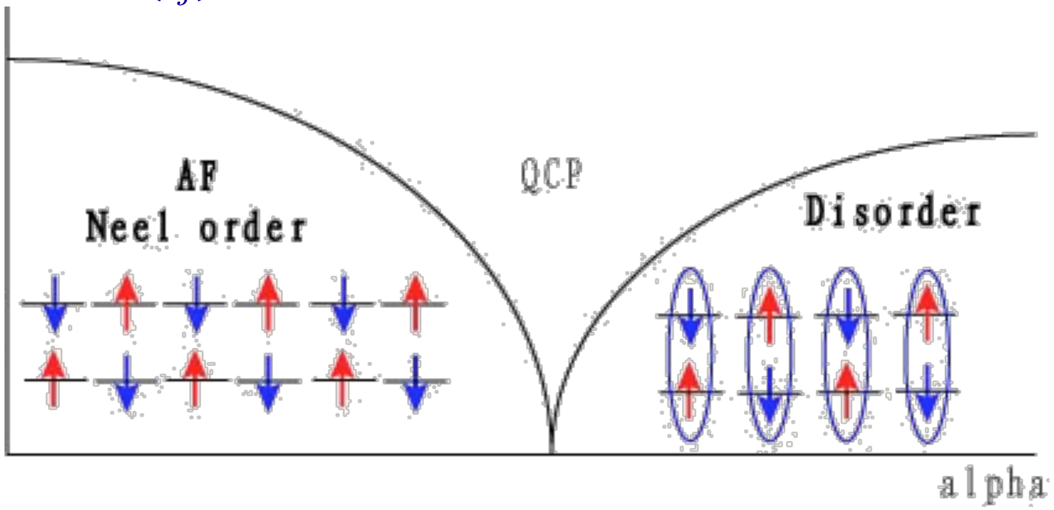
$$\begin{aligned} \alpha_k &= \cosh\theta_k a_k + \sinh\theta_k b_k^\dagger \\ \beta_k &= \sinh\theta_k a_k^\dagger + \cosh\theta_k b_k \\ \tanh 2\theta_k &= \gamma_k \end{aligned}$$

$$H = E_0 + \frac{1}{2} J z \sum_k \sqrt{1 - \gamma_k^2} (n_k^\alpha + n_k^\beta)$$

Bilayer Heisenberg model

- Naïve way doesn't work:
  1. Order-disorder phase transition

$$H = J \sum_{<ij>} (S_{1,i} \cdot S_{1,j} + S_{2,i} \cdot S_{2,j}) + J_{\perp} \sum_{i} S_{1,i} \cdot S_{2,i}$$



  2. Number of spin modes

Bilayer Heisenberg

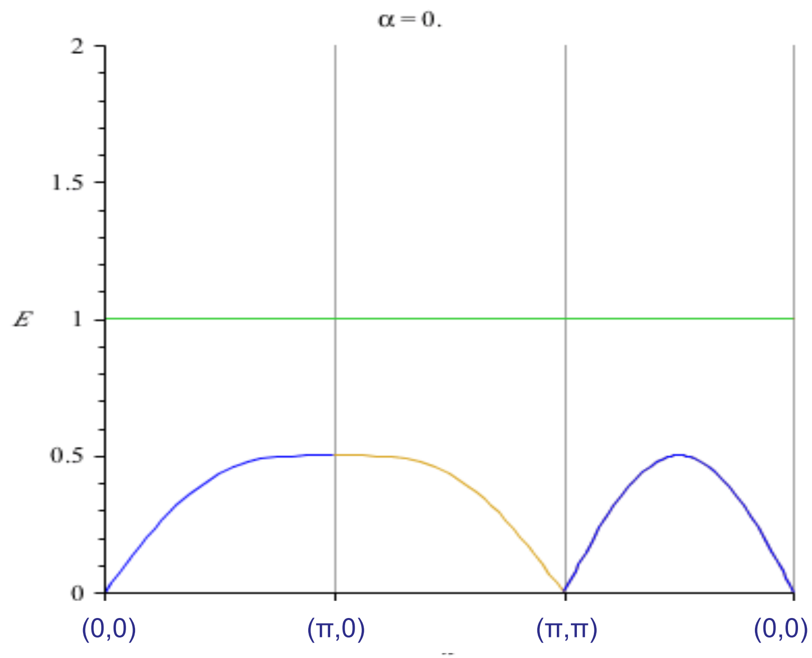
- Ground state: Singlet+Triplet competition

$$|G\rangle_i = \begin{cases} \cos\chi|0\ 0\rangle - \sin\chi|1\ 0\rangle, & i \in A \\ -\cos\chi|0\ 0\rangle - \sin\chi|1\ 0\rangle, & i \in B \end{cases}$$

- 3 different spin waves

$$\begin{aligned} e^\dagger_{iA} &= \sin\chi|0\ 0\rangle_i\langle G|_i + \cos\chi|1\ 0\rangle_i\langle G|_i \\ b^\dagger_{+iA} &= |1\ 1\rangle_i\langle G|_i \\ b^\dagger_{-iA} &= |1\ -1\rangle_i\langle G|_i \end{aligned}$$

$$\begin{aligned} e^\dagger_{k,p} &= \cosh\varphi_{k,p}\zeta^\dagger_{k,p} + \sinh\varphi_{k,p}\zeta_{-k,p} \\ b^\dagger_{k,p,+} &= \cosh\theta_{k,p}\alpha^\dagger_{k,p} + \sinh\theta_{k,p}\beta_{-k,p} \\ b^\dagger_{k,p,-} &= \cosh\theta_{k,p}\beta^\dagger_{k,p} + \sinh\theta_{k,p}\alpha_{-k,p} \end{aligned}$$

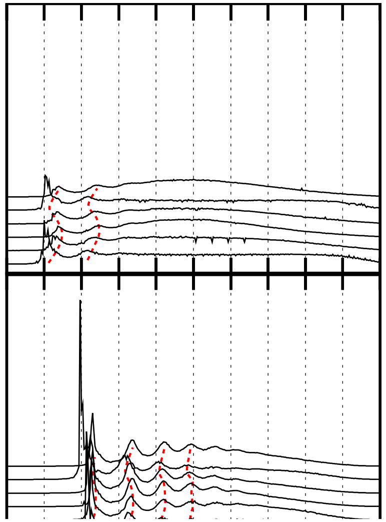


Results

- Compute self-energy

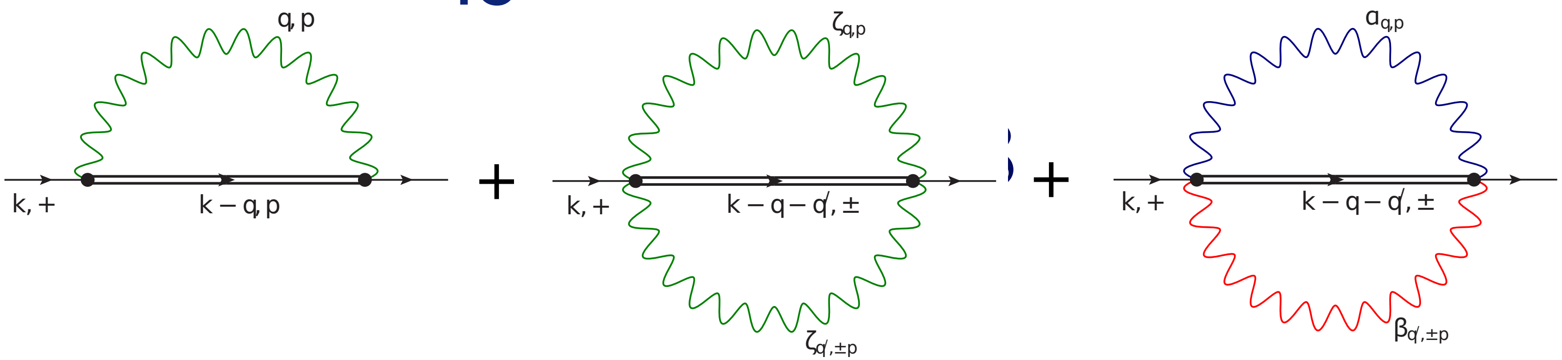
$\alpha = 0.0$

$\alpha = 0.2$



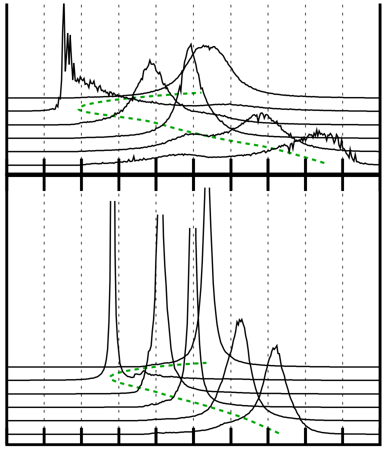
- And spectral function

$\Sigma(k,\omega) =$



$\alpha = 1.0$

$\alpha = 1.4$



Conclusion

- Interlayer excitons in Mott insulators

- A new linear spin wave theory for the Bilayer Heisenberg model

- Used to compute spectral function of interlayer exciton

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… and you for your attention!

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