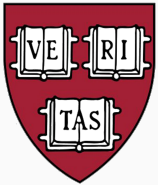
Variational wavefunctions for fractionalized Fermi liquids

Henry Shackleton

June 5, 2024

Harvard University



Variational wavefunctions for topologically-ordered Fermi liquids

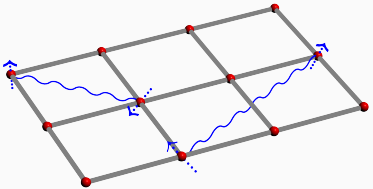
w/ Shiwei Zhang, Flatiron Institute

Capturing topological order with correlated wavefunctions

Quantum spin liquids

Capturing topological order with correlated wavefunctions

Quantum spin liquids



$$\vec{S}_i \rightarrow f^{\dagger}_{i\alpha} \vec{\sigma}_{\alpha\beta} f_{i\beta}$$

Theoretical description: Spinons + emergent gauge field

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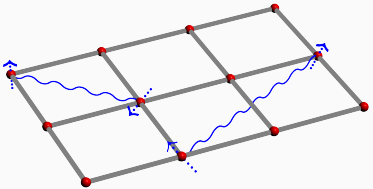

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Variational WFs: $\prod (1 - n_{i\uparrow} n_{i\downarrow}) \, |\psi_0\rangle$

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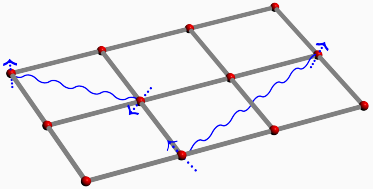

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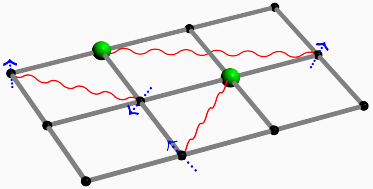
QSLs with charge fluctuations



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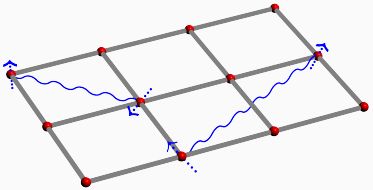

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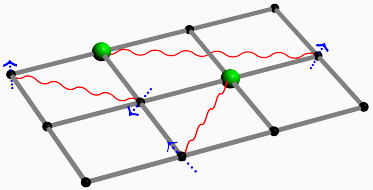

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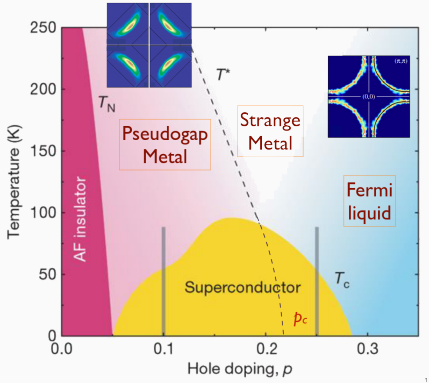
Variational WFs: this talk

Where are these variational wavefunctions useful?

Doped Mott insulators - capturing low temperature physics with TO[1]



[1]Lee, Nagaosa, and Wen, *Reviews of Modern Physics*, 2006

[2]Szasz et al., *Physical Review X*,. 2020

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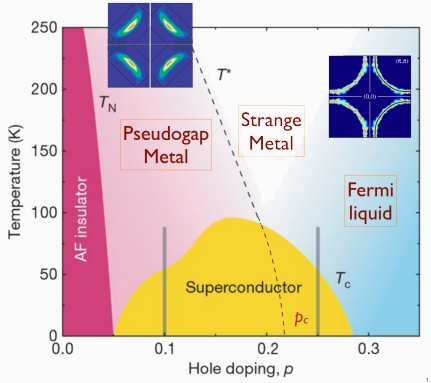
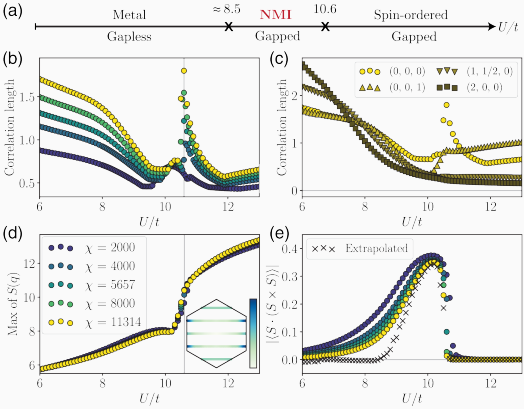


TO near metal/insulator transitions[2]



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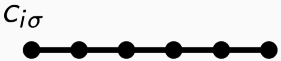

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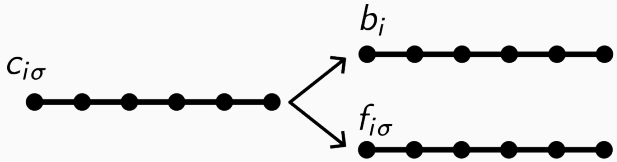

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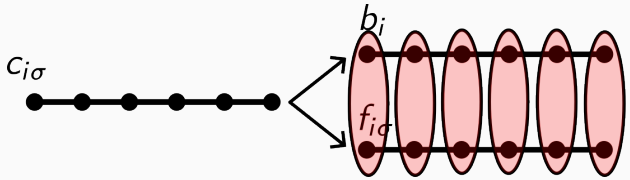

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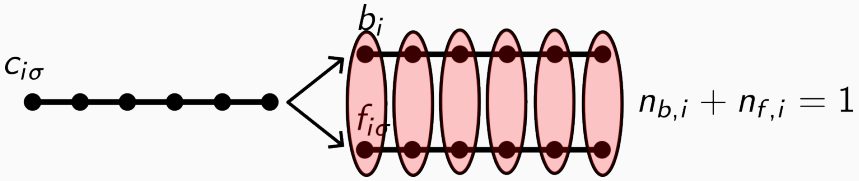

Problem: bosonic (permanent) wavefunctions not numerically tractable

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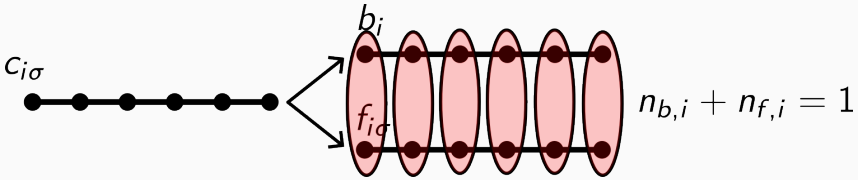

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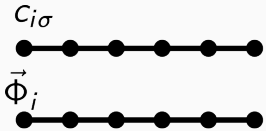

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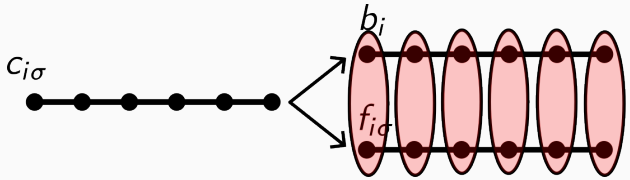

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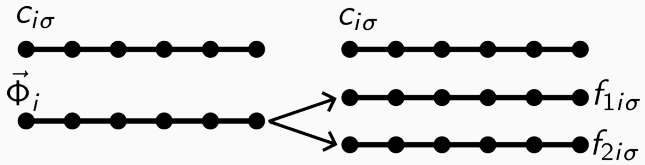

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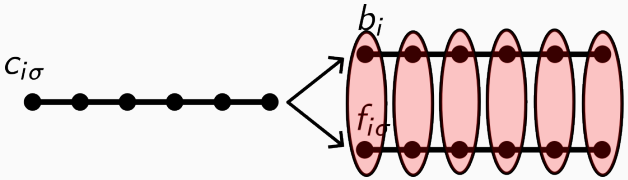

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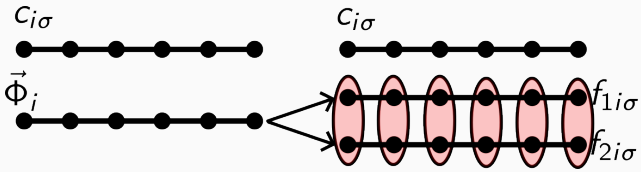

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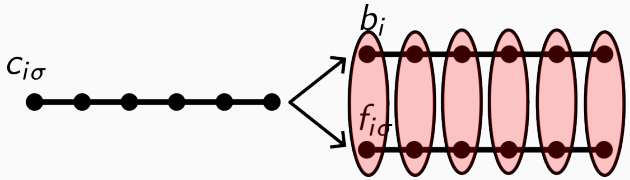

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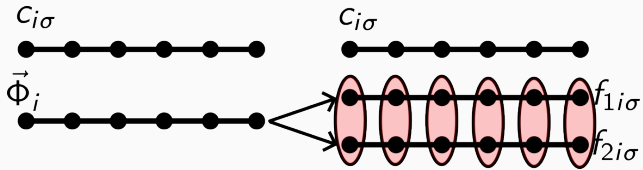

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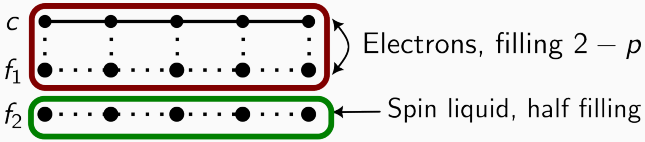
Fully fermionic mean-field ansatz, projection possible with Monte Carlo sampling

Mean-field analysis on square lattice yields pseudogap-like features[3]



Mean-field picture: electron-like quasiparticles
+ decoupled spin liquid

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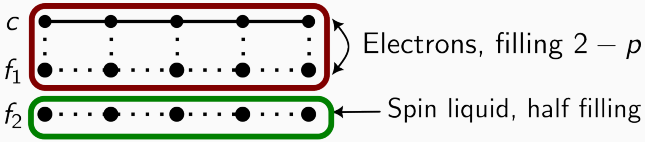

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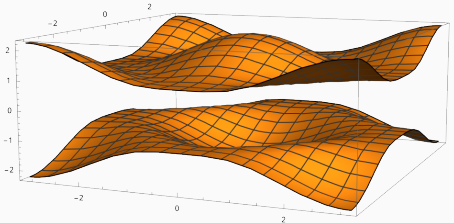

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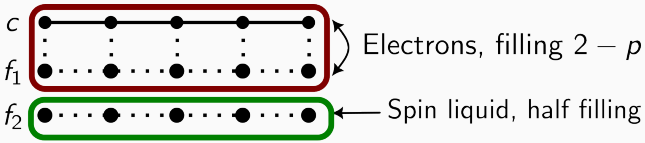

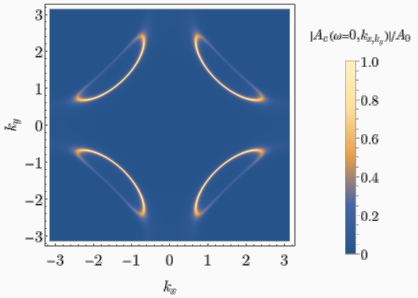

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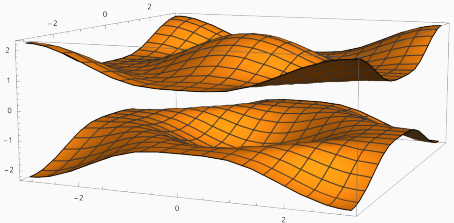

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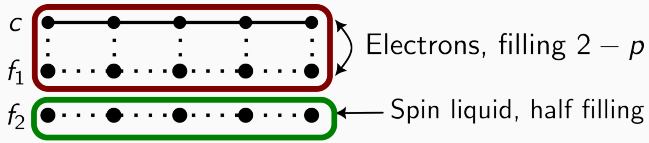

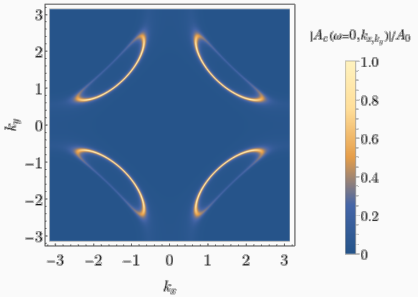

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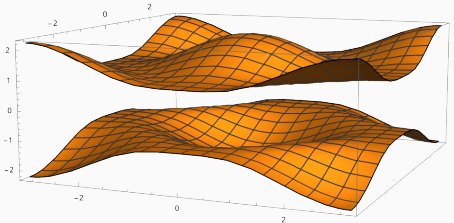

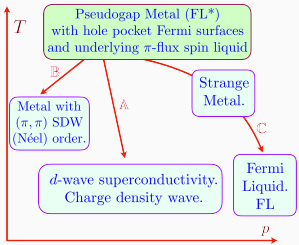

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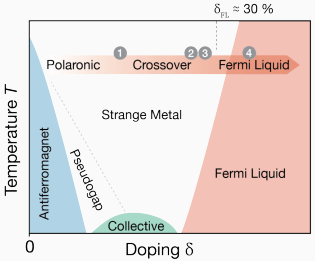
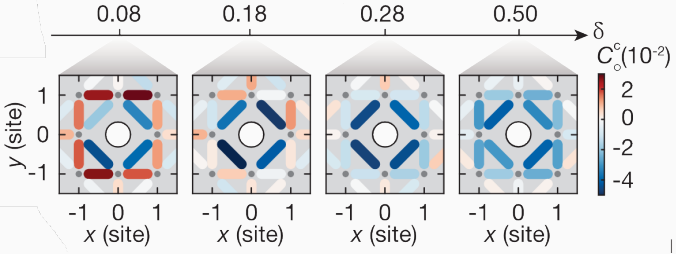
Polaronic correlations central for capturing doped Mott insulators

$$H = t \sum_{\langle ij \rangle} c^{\dagger}_{i\sigma} c_{j\sigma} + U \sum_{i} n_{i\uparrow} n_{i\downarrow}$$





Koepsell et al., Science, 2021

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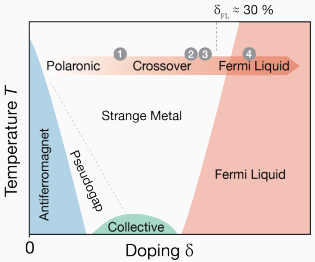
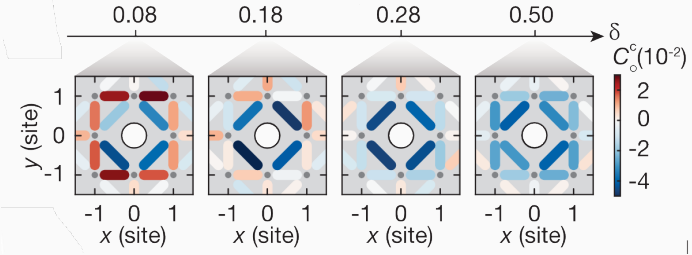


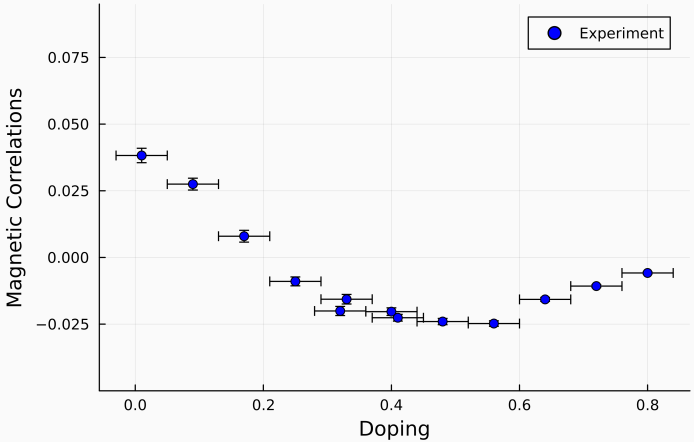


Do these wavefunctions support polaronic correlations?

Koepsell et al., Science, 2021

Nearest neighbor magnetic correlations ($U/t = 7.4$)

Polaronic correlations probed by multipoint correlator $\langle h_i S^z_j S^z_k \rangle$



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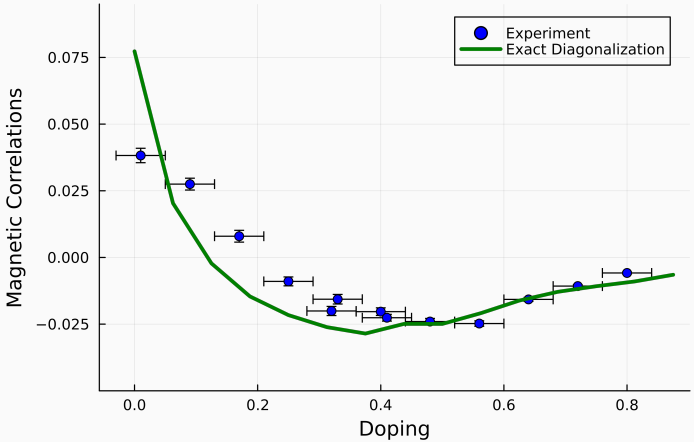

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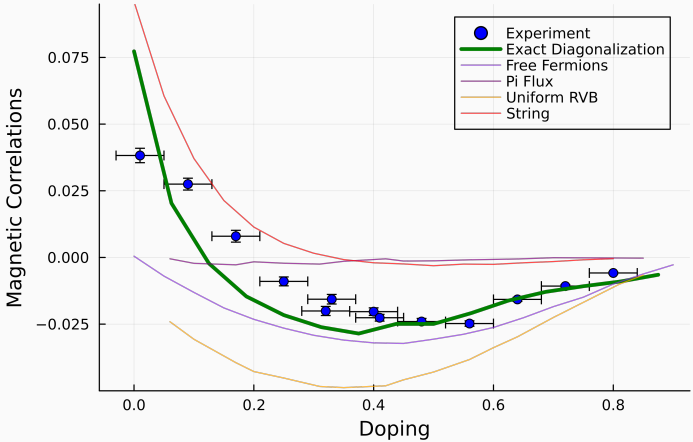

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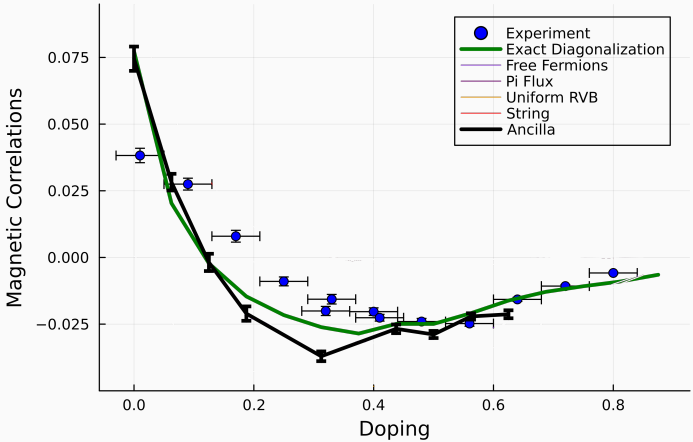

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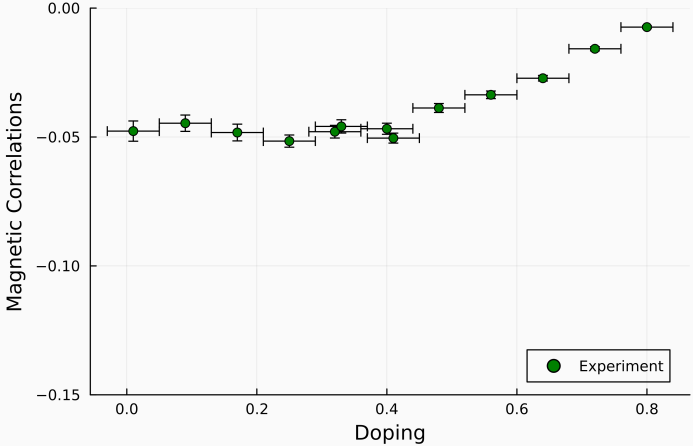

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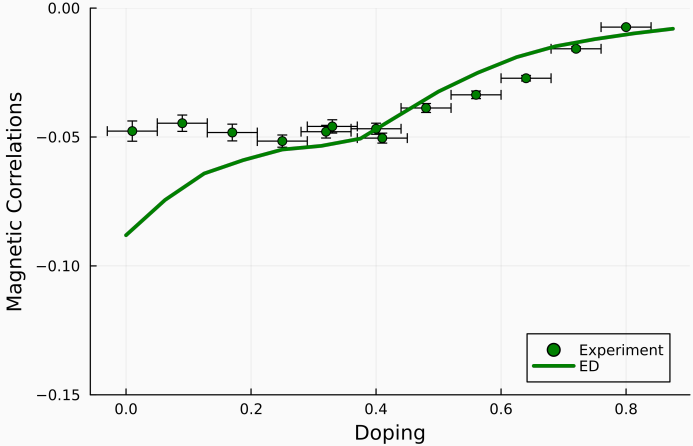

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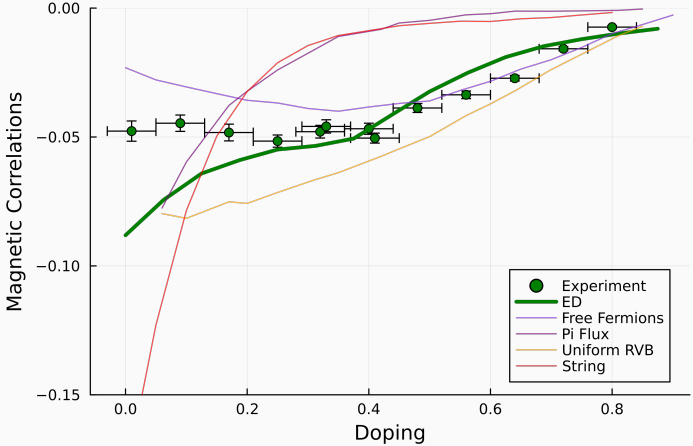

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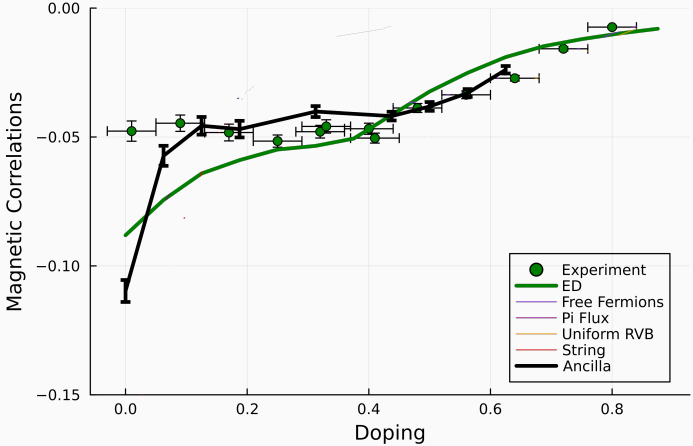

Conclusions and future directions

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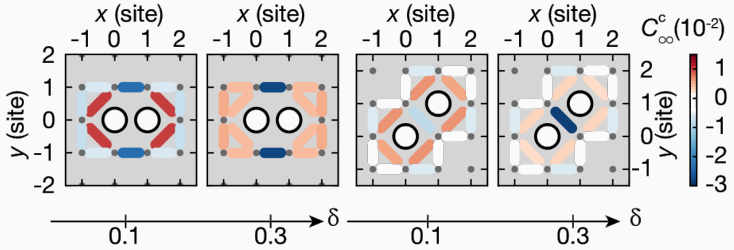
- Respectable energetics - low-energy states
- Can these WFs reconstruct higher-point correlators?



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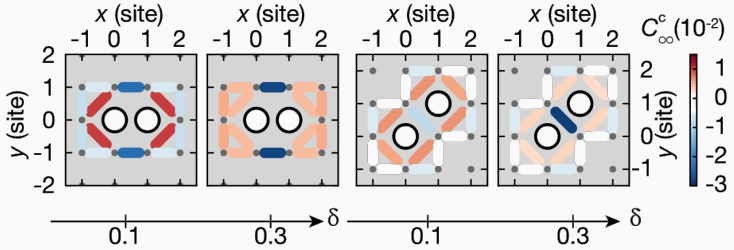
Conclusions and future directions

- Variational WFs of fractionalized Fermi liquids capable of capturing multi-point correlators of doped Hubbard models
- Respectable energetics - low-energy states
- Can these WFs reconstruct higher-point correlators?



- CSL on triangular lattice Hubbard model - which CSL?[4]

[4] Song, *Physical Review B*,. 2021.

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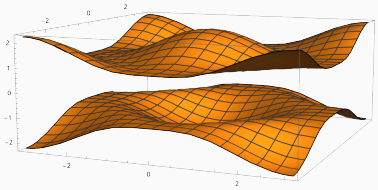

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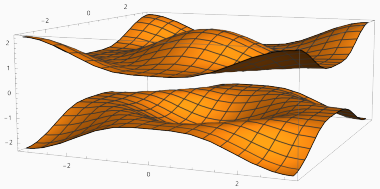

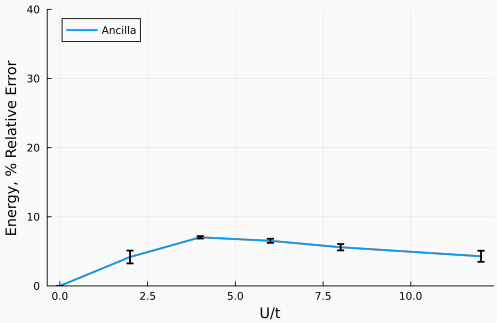

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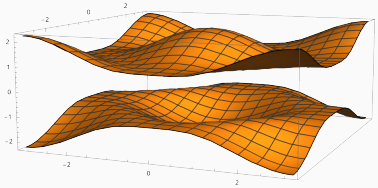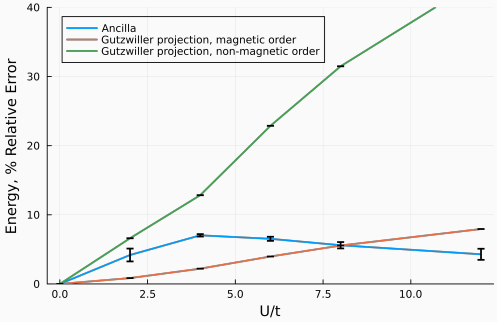
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