Chiral Spin Liquid in the Kagome Lattice

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Abstract

We report on the investigation of a putative chiral spin liquid in the Kagome Lattice with a modified Heisenberg Model inspired by the material Kapellasite. Our variational monte carlo results via gutzwiller projected wavefunctions indicate that a chiral spin liquid *ansätz* with staggered$\pm\frac{\pi}{2}$flux in the triangles and 0 flux in the trapezoids is competitive for $\frac{J_d}{J_\chi} > 0$. We also investigated the stability of this spin-liquid state with respect to ordered phases known to occur in the model.

CQSL in the Kagome Lattice

The Kagome lattice is a rich environment to host exotic spin liquids states (QSL) [1]. These QSLs may vary from algebraic U(1) to chiral spin liquids (CQSL) [2]. Inspired by the material Kapellasite, which presents a broad continuum on the momentum structure in inelastic neutron scattering experiments [3], we investigate the modified Heisenberg model [4]

$$\mathcal{H} = J_1 \sum_{<i,j>} \boldsymbol{S}(\boldsymbol{r_i}) \cdot \boldsymbol{S}(\boldsymbol{r_j}) + J_d \sum_{ij \in \hexagon} \boldsymbol{S}(\boldsymbol{r_i}) \cdot \boldsymbol{S}(\boldsymbol{r_j}) + J_\chi \sum_{ijk \in \triangle\triangledown} \boldsymbol{S}(\boldsymbol{r_i}) \cdot [\boldsymbol{S}(\boldsymbol{r_j}) \times \boldsymbol{S}(\boldsymbol{r_k})]$$

with$J_1 < 0$ interactions on the first neighbor inspired by the previously mentioned material, $J_d > 0$ interactions in the diagonals of each unit cell and $J_\chi < 0$ on up and $J_\chi > 0$ on down elementary triangles of the Kagome lattice. The sublattices are weakly coupled via the diagonal interaction. The Projective Symmetry Group extension to CQSLs [5] provide three different choices of gauge fluxes through the elementary plaquettes for the studied *ansätz* in the model.

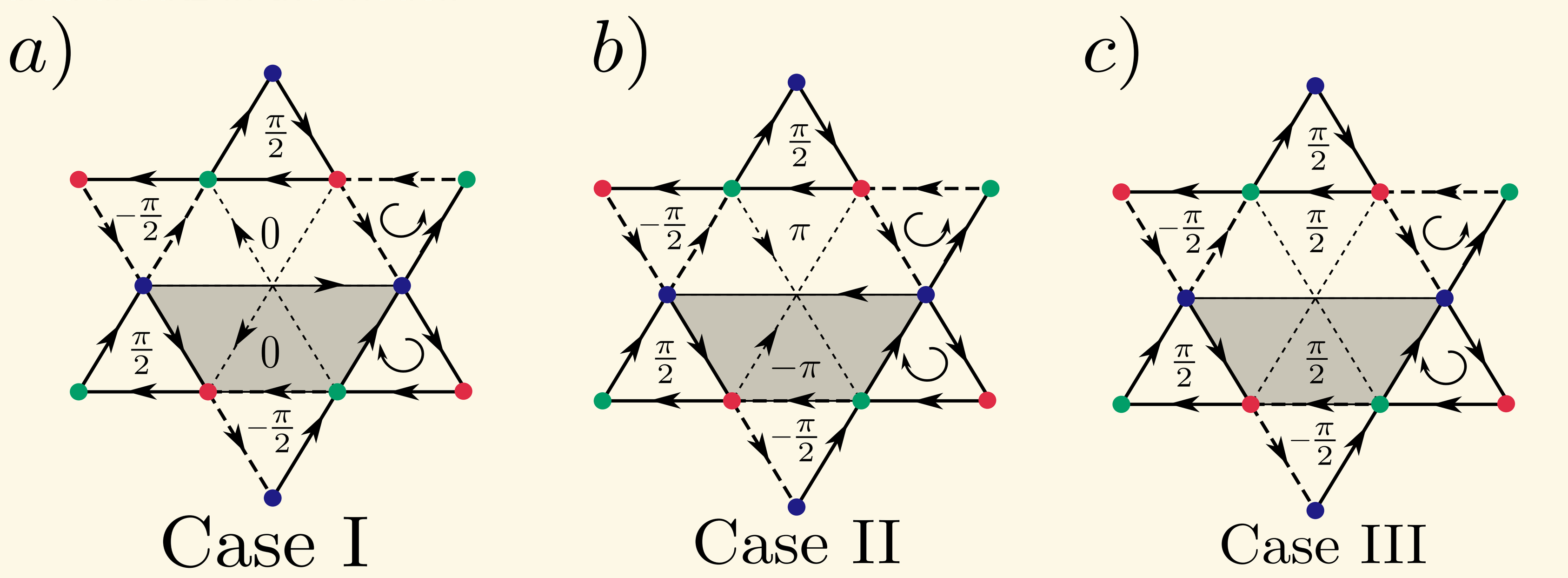


Figure 1: The physical *ansätz* explored in the modified Heisenberg Hamiltonian.

Classical Phase Diagram

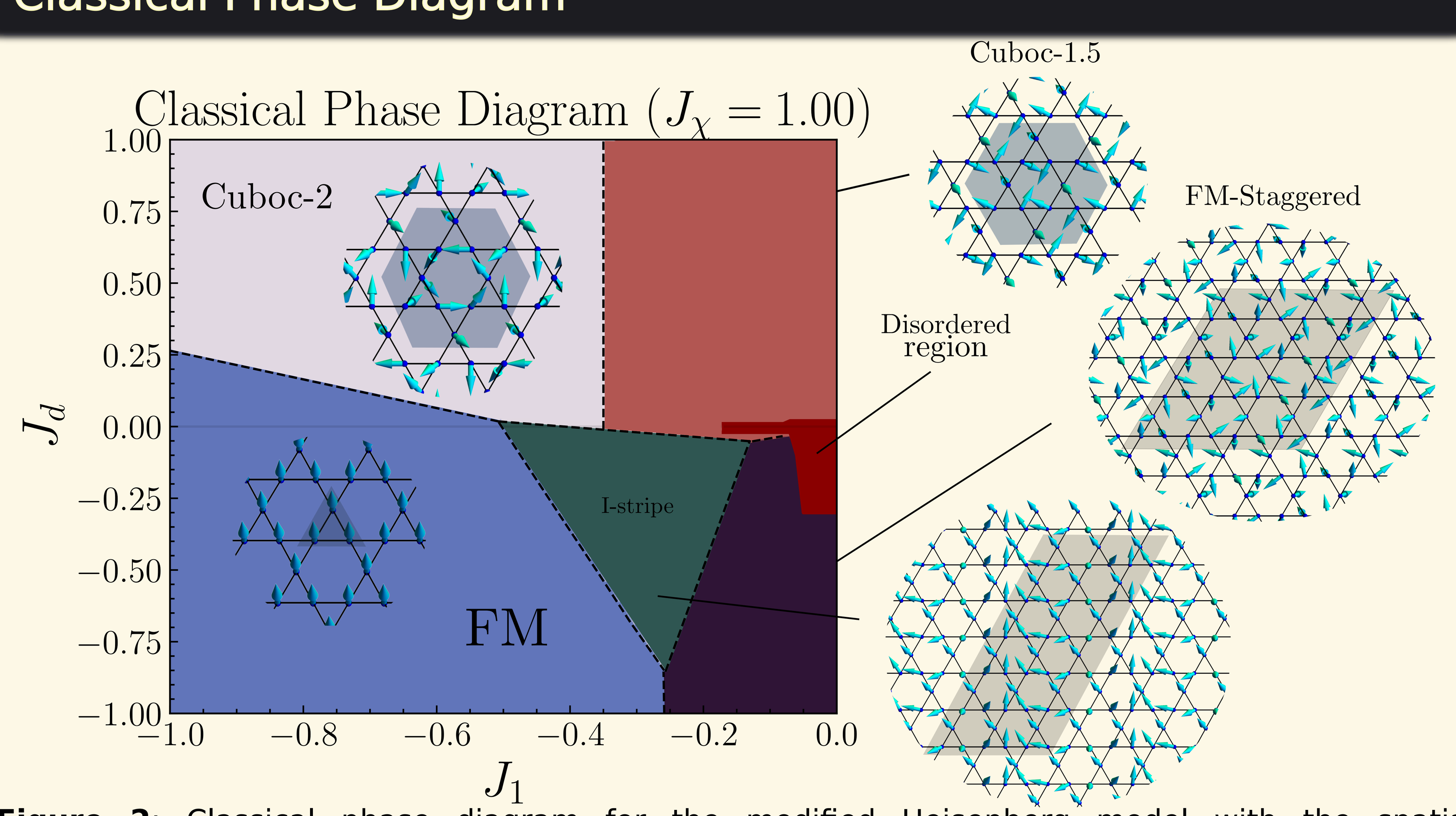
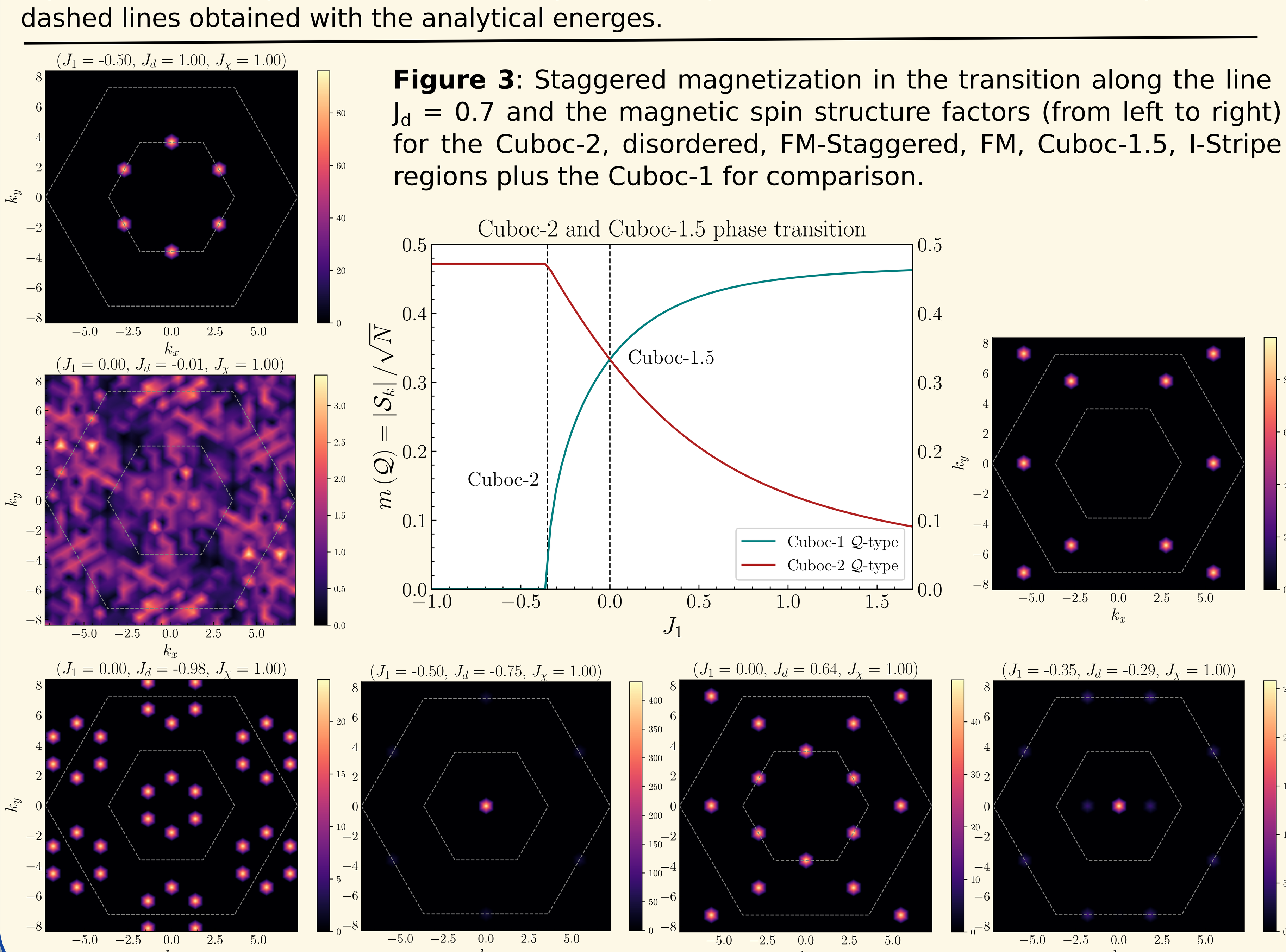


Figure 2: Classical phase diagram for the modified Heisenberg model with the spatial representation of spins for each ordered phase. The phase boundaries are delimited by the black dashed lines obtained with the analytical energes.

Figure 3: Staggered magnetization in the transition along the line J_d = 0.7 and the magnetic spin structure factors (from left to right) for the Cuboc-2, disordered, FM-Staggered, FM, Cuboc-1.5, I-Stripe regions plus the Cuboc-1 phase for comparison.



Variational Monte Carlo (VMC)

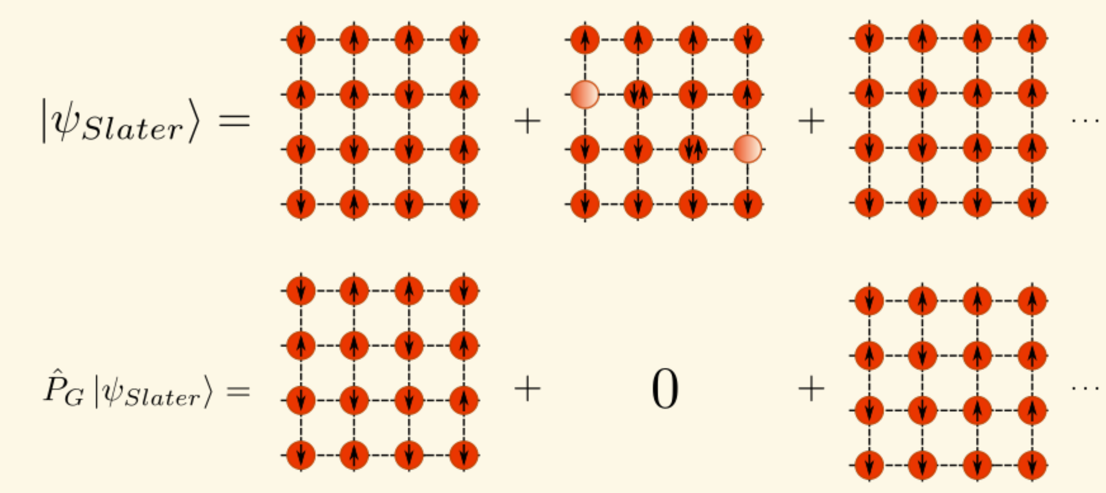


Figure 4: Pictorial representation of the projected wavefunctions.

Using a parton construction to represent the spin degrees of freedom in terms of fermionic ones,

$$\hat{S}_i^+ = f_{i\uparrow}^\dagger f_{i\downarrow}, \quad \hat{S}_i^- = f_{i\downarrow}^\dagger f_{i\uparrow}, \quad \hat{S}_i^z = \frac{1}{2}(n_{i\uparrow} - n_{i\downarrow}),$$

we calculated the ground state energy of the ansätz with a VMC based on Guztwiller Projected MFT wave functions [6], with the no double occupancy constraint imposed at each site:

$$|\Psi\rangle = \hat{P}_G |\Psi_{MFT}\rangle = \prod_{\boldsymbol{i}} (n_{\boldsymbol{i}\uparrow} - n_{\boldsymbol{i}\downarrow})^2 |\Psi_{MFT}\rangle$$

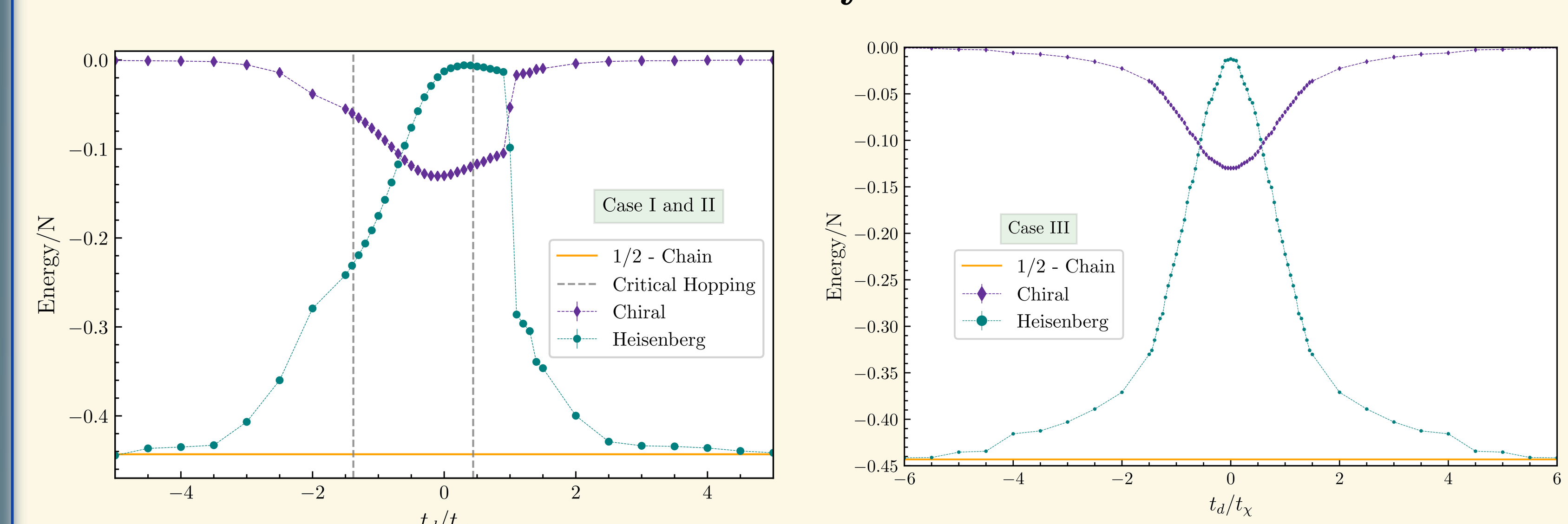


Figure 5: Energy contribution for each *ansätz* by the Heisenberg (green) and chiral (purple) interactions. The gray dashed lines indicate a region of stability for Cases I and II [4]. The AFM chain solution via Bethe's *ansätz* is plotted in orange for comparison.

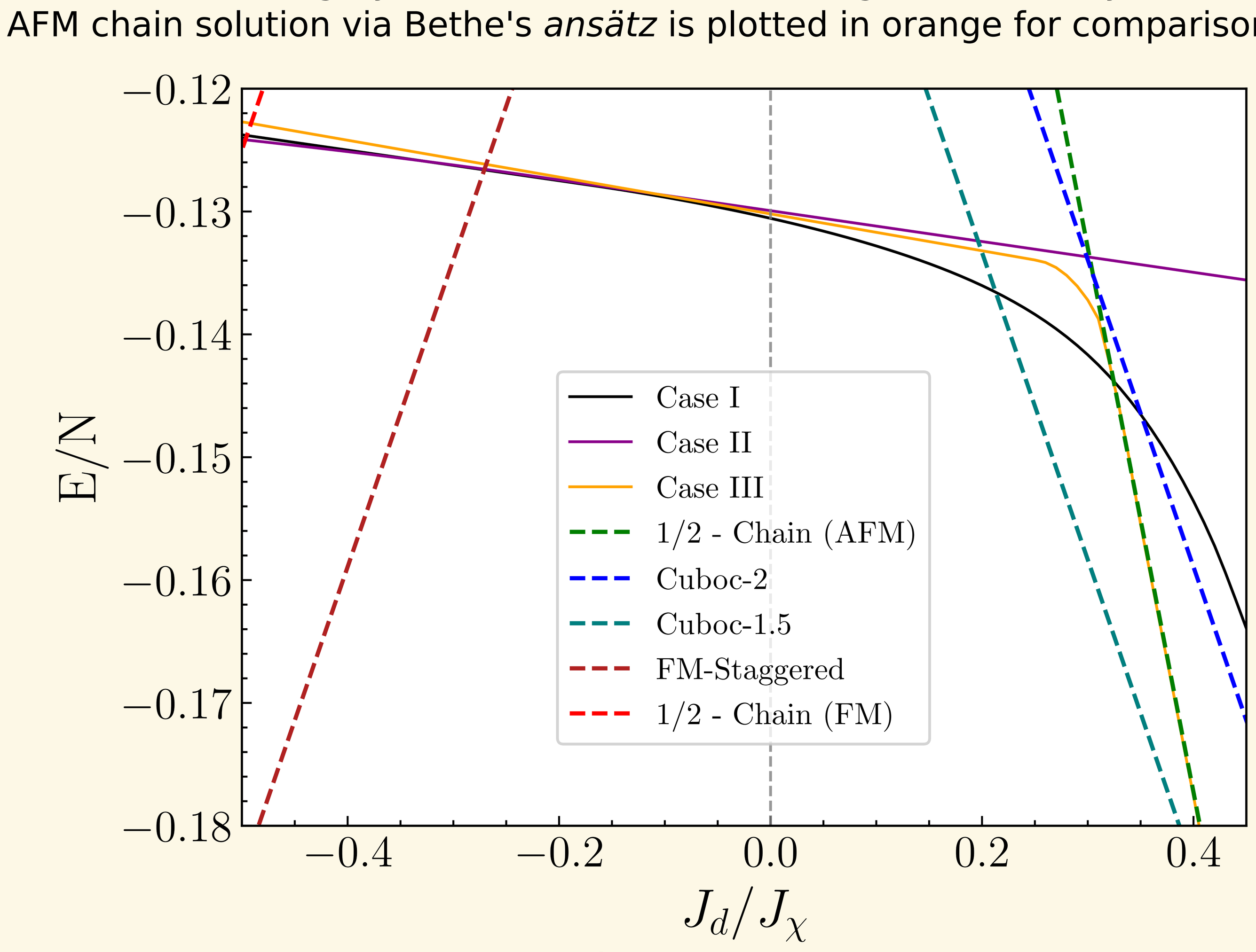


Figure 6: VMC ground state energy results and comparison with known ordered phases.

Conclusion

We have found numerical evidence that the aforementioned CQSL in the Kagome Lattice, which is equivalent to other CQSL studied previously [7,8], is, indeed, competitive. The VMC results agree with the mean-field theory ones in the sense that Case I is the most competitive ansätz. A delimited region for the existence of the CQSL is also obtained before correlations of the cuboc-2 state type arise, or when the regime of decoupled chains is reached. Currently we are investigating the quantum phase diagram of the model with the additional J_1 interaction.

For further inquiries you can send an e-mail to joaogustosds@ifsc.usp.br or join me in the google meet call https://meet.google.com/dwo-zccm-ijc?authuser=1

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