Workshop on Tensor Networks for Chiral Topological Matter
International Quantum Tensor Network
Cosener's House, Abingdon, Dec 12-14, 2023

Tuesday 12.12.:

Morning: Arrival & Registrations - Garden Room available for open discussions from 9am (coffee / snacks available)

12:45 pm: Hot Lunch served

Session 1: Theoretical foundations

2pm – 3pm: Thorsten Wahl: Overview - PEPS for Chiral Phases (45+15)
3pm – 3:45pm: Mark Arildsen: Entanglement spectra of chiral PEPS states (30-15)

3:45pm – 4:30pm: Coffee break

4:30pm- 5:30pm: German Sierra: Tensor Networks and CFT (45+15)
5:30pm Kick-off discussion:
Generate ideas on what participants would like to achieve during the workshop
7:15pm – Dinner

Wednesday 13.12.:

Session 2 (am): FQHE and relations to CFT

9am-10m Nicolas Regnault (MPS representations for FQH: Interfaces and Fractional Chern Insulators) (45+15 minutes)
10am-10:45am Coffee Break
10:45-11:30 Anne Nielsen: Fractional quantum Hall effect on fractals (30+15)
11:35-12:20 Matteo Rizzi: PEPS calculations for FQH states (30+15)

12:30-2pm Lunch / Discussions

Session 3 (pm): Chiral spin liquids

2pm – 3pm Juraj Hasic: PEPS studies of Chiral Spin Liquids (overview)
3pm – 3:45pm Matthieu Mambrini: "SU(N) symmetric PEPS : construction and applications"
3:45pm – 4:30pm: Coffee break
4:30pm – 5:15pm: Laurens Vanderstraeten: "Low-energy dynamics and quasiparticles with MPS and PEPS"
5:30pm – 6:45pm Panel: Future Directions for chiral TNs

7:30pm Festive Dinner

Thursday 14.12.:

Session 4: New theoretical frameworks (research talks)

9am-9:45am:	Carolin Wille (state-sum construction)
9:45am-10:30am:	Maria Hermanns: Majorana representations for 3D Chiral spin liquids with crystalline Z2 gauge order
10:30am- 11:15am	Coffee break & Discussions
11:15-12pm:	Adrian Franco Rubio: TBC
12pm-12:45	Concluding discussion panel: promising directions for theoretical frameworks
12:45-2pm	Lunch / Coffee
2pm – 5pm	Time for individual discussions

Talk Abstracts:

(as received to date)

Maria Hermanns: 3D Chiral spin liquids with crystalline Z2 gauge order

Quantum spin liquids are topologically ordered phases: they are not associated with broken symmetries or long-range order, but rather long-range entanglement. Chiral spin liquids are exceptional, because they spontaneously break time-reversal symmetry. In this talk, I focus on chiral spin liquids occurring for 3D generalizations of Kitaevs honeycomb model, where the competition of geometric and exchange frustration leads to a particularly rich physics.

Matthieu Mambrini: SU(N) symmetric PEPS - construction and applications

In the context of SU(N) spin systems, I will show how discrete and continuous symmetries can be implemented at a local (tensor) level to design manifolds of wavefunctions with controlled broken/unbroken symmetries. This framework is not only useful for engineering particular states, such as e.g. chiral spin liquids, but also in groundstate optimisation procedures for a given hamiltonian.
I will explain the main ideas of this construction and illustrate with a recent example of SU(3) CSL on the kagome lattice [Y.Xu et al. Phys. Rev. B 108, 195153 (2023)].

Anne Nielsen: Fractional quantum Hall effect on fractals

The Laughlin and Moore-Read states can be formulated as infinite-dimensional-matrix product states by writing them as correlation functions in conformal field theory. The construction allows us to generalize the Laughlin and Moore-Read states to arbitrary lattices embedded in two dimensions and to find few-body, non-local, exact parent Hamiltonians for the states. We numerically and analytically study the properties of the Laughlin state on fractal lattices with different Hausdorff dimensions. We find that the states support anyons with fractional statistics as expected for the Laughlin state, but the states do not necessarily follow the area law. Finally, we optimize local Hamiltonians to have maximal ground state overlap with the Laughlin state.

References:
Phys. Rev. Research 2, 023401 (2020)
Phys. Rev. B 105, 085152 (2022)
J. Stat. Mech. 2023, 053103 (2023)
Phys. Rev. A 107, 063315 (2023)

Matteo Rizzi: Fractional quantum Hall states with variational Projected Entangled-Pair States

An important class of model Hamiltonians for investigation of topological phases of matter consists of mobile, interacting particles on a lattice subject to a semi-classical gauge field, as exemplified by the bosonic Harper-Hofstadter model. A unique method for investigations of two-dimensional quantum systems are the infinite projected-entangled pair states (iPEPS), as they avoid spurious finite size effects that can alter the phase structure. However, due to no-go theorems in related cases this was often conjectured to be impossible in the past.
Here, we show that upon variational optimization the infinite projected-entangled pair states can be used to this end, by identifying fractional Hall states in the bosonic Harper-Hofstadter model. The obtained states are characterized by showing exponential decay of bulk correlations, as dictated by a bulk gap, as well as chiral edge modes via the entanglement spectrum.
We discuss some technical aspect of the algorithm, too: in particular, the incorporation of automatic differentiation, which has ultimately enabled a new, flexible way for variational simulation of ground states and excited states, thus overcoming accuracy and convergence problems of previously known methods.

arXiv:2309.12811 & arXiv:2308.12358

Germán Sierra: Chiral TN and CFT

Tensor Networks and Conformal Field Theory are powerful tools to study the physics of low dimensional quantum many body systems.
In one spatial dimension the MPS has successfully described models satisfying the entanglement area law, while critical systems has been well characterized by CFT.
In two spatial dimensions, the capabilities of these methods are not fully understood, especially in systems with topological properties. The objective of this talk is to combine these methods with the aim of shedding some light on the problems that appear in their applications.

Laurens Vanderstraeten (Brussels): Low-energy dynamics and quasiparticles with MPS and PEPS

Abstract: I will give an overview of different tensor network methods for accessing the dynamical properties of 2-D quantum lattice models, with a focus on chiral systems.