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Model wavefunctions for an interface between lattice Laughlin and Moore-Read states

Blazej Jaworowski
Model wavefunctions for interfaces between lattice Laughlin and Moore-Read states

Błażej Jaworowski, Anne E.B. Nielsen

**Motivation:** What happens at non-Abelian FQH interfaces?

- Interfaces can have topological structure which can generate nontrivial phenomena (e.g. additional topological degeneracy).
- Few microscopic works – ED is hard. Model wavefunctions can help.
- Almost all of them describe continuum systems
- Anyons are important, but we are not aware of any microscopic studies.

**Method:** Model wavefunctions from CFT correlator of two types of vertex operators,

\[
\psi(n) = \langle 0 | \prod_{i=1}^{N_L} V_{i,MR}(z_i, n_i) \prod_{i=N_L+1}^{N} V_{i,Laughlin}(z_i, n_i) | 0 \rangle,
\]

and Monte Carlo study of their properties (GS+quasiholes+quasielectrons).
**Ground state:** particle density, correlation function, entanglement entropy

- **Anyons:** charge and statistics of anyons before and after crossing the interface.
- **Multiple islands:** topological degeneracy.
A random unitary circuit model for black hole evaporation

Christoph Sunderhauf
A random unitary circuit model for black hole evaporation
Lorenzo Piroli*, Christoph Sünderhauf*, Xiao-Liang Qi (* contributed equally)
JHEP 2020: 63 (2020), arXiv: 2002.09236

Coupling to environment
$W_{l,m}$ SWAP

Intrinsic dynamics
$U_{i,j}$ Haar-random
(w/ & w/o charge conservation)
A random unitary circuit model for black hole evaporation
Lorenzo Piroli*, Christoph Sünderhauf*, Xiao-Liang Qi (* contributed equally)
JHEP 2020: 63 (2020), arXiv: 2002.09236
AKLT-states as ZX-diagrams: diagrammatic reasoning for quantum states

Richard D.P. East
AKLT-states as ZX-diagrams: diagrammatic reasoning for quantum states

Richard D. P. East, John van de Wetering, Nicholas Chancellor, and Adolfo G. Grushin, arXiv:2012.01219.

- Tensor networks have found numerous applications.
- They are an excellent graphical representation of states.

But
- Diagrammatic representations of tensor networks are an excellent aid, but not a calculation tool.

Our solution
- The ZX calculus is a diagrammatic language for qubit tensor networks.
- We can perform calculations by only altering the diagrams.

(a) Singlet
\[
\begin{align*}
\text{Singlet} &= \frac{1}{\sqrt{2}} \langle |01\rangle - |10\rangle \\
&\propto \frac{1}{\sqrt{2}} (|10\rangle - |01\rangle)
\end{align*}
\]

(b) Projector
\[
\begin{align*}
\text{Projector} &= |+\rangle \langle 11| + |0\rangle \frac{\langle 10| + \langle 01|}{\sqrt{2}} + |-\rangle \langle 00|
\end{align*}
\]

\[
\propto \frac{1}{\sqrt{2}} (|10\rangle - |01\rangle)
\]

(c) AKLT state

(d) MPS equivalence

\[
\begin{align*}
\propto M^{[n]+1} &\quad \propto M^{[n]0} &\quad \propto M^{[n]-1}
\end{align*}
\]
Things you can do

- In the 1D AKLT state we identify the edge states, retrieve the MPS representation, and prove the existence of a string order diagrammatically.

- In 2D we simplify the proof that the 2D AKLT state is a universal resource.

\[
\begin{array}{c}
\frac{1}{2} = \frac{1}{2\sqrt{2}} \\
\pi (\pi c) (f) = \pi (c) (f) = \frac{1}{2\sqrt{2}} \\
\end{array}
\]

\[
\begin{array}{c}
\frac{1}{2} = \frac{1}{2} \\
\pi (ex) (f) = \pi (c) (f) = \pi \\
\end{array}
\]

\[
= 2 \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix} = \frac{1}{\sqrt{6}} M[n]+1
\]

Example of a diagrammatic calculation.
Anderson complexes: Bound states of atoms due to Anderson localization

Krzysztof Giergiel
Cold atomic system driven by time periodic external force can give rise to **time crystals**.

Disordered time periodic driving gives rise to **Anderson localization in time domain**.

Cold atoms by **Feshbach** resonance give control over interaction strength (even sign).

It is natural to investigate **periodic driving** of internal interaction strength instead of external force.

If this interaction strength varies in disordered fashion in time what will we see?
What?
Anderson Complexes - Bound states of atoms due to Anderson localization

\[ H = \frac{p_{12}^2}{m^*} + V(r_{12}), \]

\( V(r_{12}) \) is a random function with infinite support.
In localized regime one expect exponential localization in relative distance:
Continuous matrix product operator approach to finite temperature quantum states

Wei Tang
CONTINUOUS MATRIX PRODUCT OPERATOR APPROACH TO FINITE TEMPERATURE QUANTUM STATES

(a) $L = \infty$

(b) $\langle l | \ T \ | r \rangle$
Correlation-enhanced Neural Networks as Interpretable Variational Quantum States

Agnes Valenti
Correlation-enhanced Neural Networks as Variational Quantum States

RBMs with correlators

Topological phases

Excited states without symmetries

In preparation:
A Valenti (ETH Zürich), E Greplova, NH Lindner and SD Huber
Efficient MPS methods for extracting spectral information on rings and cylinders

Maarten Van Damme
Efficient MPS methods for extracting spectral information on rings and cylinders

Quasiparticle ansatz

$$\sum_{i} A_i^l \cdots B_i \cdots A_N^r$$  \hspace{2cm} (1)

Applied to

- finite mps
- cylinder infinite mps
Efficient MPS methods for extracting spectral information on rings and cylinders

(a) spin 1 Heisenberg, OBC
(b) critical Ising, PBC
(c) cylinder Ising, $p_y = 0$
(d) Magnon Hubbard, different $p_y$
Generating Function for Tensor Network Diagrammatic Summation

Wei-Lin Tu
GENERATING FUNCTION FOR TENSOR NETWORK
DIAGRAMMATIC SUMMATION

Wei-Lin Tu

Institute for Solid State Physics (ISSP), University of Tokyo

WT, H.-K. Wu, N. Schuch, N. Kawashima, and J.-Y. Chen, arXiv:2101.03935 (2021)

wtu@issp.u-tokyo.ac.jp
Tensor Networks:

One-particle excitation:

\[ |\Phi_k(B)\rangle = \sum_{j=0}^{N-1} e^{-ik j \tilde{j} j} |B\rangle |s_1\rangle |A\rangle \ldots |A\rangle \]

Static structural factor:

\[ S^{\alpha, \beta}(k) = \frac{1}{N} \sum_{j,j'=1}^{N} e^{ik \cdot (r_j - r_{j'})} \langle \hat{O}_j^\alpha \hat{O}_{j'}^\beta \rangle \]

Generating function

\[ |G_\Phi(\lambda)\rangle = \begin{array}{cccc} \lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \end{array} \]

\[ MPS_j(\lambda) = A + \lambda e^{-ik r_j B} \]

\[ \hat{G}_{SF}(\lambda) = \begin{array}{cccc} \lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \\
\lambda e^{-ik r_j B} \end{array} \]

\[ \hat{O}_j^\beta(\lambda) = I + \lambda e^{-ik r_j B} \hat{O}_j^\beta \]

With the help of desired generating functions, the number of tensors under consideration can be largely reduced!
Homogeneous Floquet time crystal from weak ergodicity breaking

Hadi Yarloo
Horizon bound in QFT

Ivan Kukuljan
Horizon bound in QFT

- Prepare a QFT in a short range correlated initial state $\langle O(x)O(y) \rangle_C \propto e^{-|x-y|/\xi}$
- Quench $H_0 \rightarrow H$
- Correlations spread within a horizon $|\langle O(t,x)O(t,y) \rangle_C| < \kappa e^{-\max\{|x-y|-2ct|/\xi_h,0\}}$
- Proven in CFT, demonstrated analytically and numerically in many systems, observed experimentally

$\rightarrow$ Believed to be a general property of quantum systems
Oscillating infinite range correlations of currents

\[ C_\mu(t, x, y) = \langle J^\mu(t, x) J^\mu(t, y) \rangle \]

Found in the sine-Gordon model (using bosonisation and truncated Hamiltonian methods)
IK, Sotiriadis, Takács, JHEP 2020, 224

Recently found in gauge theory – 1+1D quantum electrodynamics (using THM)
IK, arXiv:2101.07807 [hep-th]

Related to nontrivial field topology
Investigation of the Néel phase of the frustrated Heisenberg antiferromagnet by differentiable symmetric tensor networks

Juraj Hasik
**HOW TO iPEPS:**
The case of J1-J2  
Juraj Hasik, Federico Becca, Didier Poilblanc

I. Gradient based optimization with AD  

II. Extract symmetry structure  

III. Analyze with finite correlation-length scaling  

Investigation of the Néel phase of the frustrated Heisenberg antiferromagnet by differentiable symmetric tensor networks, *SciPost Phys.* 10, 012 (2021)
Measurement-induced transition in random quantum circuits: from stroboscopic to continuous

M. Szyniszewski
Quantum circuit

- Random unitary evolution (U) and weak measurements (M)

- What is the stationary state entanglement?

\[ U \text{ favours volume law.} \]
\[ M \text{ (if strong) favours area law.} \]

Stroboscopic measurements: phase diagram

\[ \text{var}(S_\infty) \]

\[ \text{Measurement frequency } p \]

\[ \text{Measurement strength } \lambda \]

Area law

Volume law
Continuous measurements: phase transition

- Phase transition still present when continuous measurement is used

Universality of the phase transition

Discrete and continuous regimes seem to be smoothly connected and exhibit similar critical exponents. Universality between the two regimes?
Non-separable time-crystal structures on the Mobius strip

Arkadiusz Kuros
Non-separable time-crystal structures on the Möbius strip

Krzysztof Giergiel\textsuperscript{1}
Arkadius Kuroś\textsuperscript{3}
Arkadius Kosior\textsuperscript{2}
Krzysztof Sacha\textsuperscript{1}

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Abstract

Periodically driven many-body quantum systems provide a comfortable platform for modelling crystalline structure in the time dimension which opens a path to realize temporal condensed matter physics and explore novel phenomena. It has been already shown that the time domain can host Anderson localization, Mott insulator phase\textsuperscript{1}, topological phases\textsuperscript{2}, dynamical phase transitions\textsuperscript{3}, quasi-crystals\textsuperscript{4} and fractional time crystals\textsuperscript{5}.

Here, we present a simple implementation of non-separable two-dimensional lattices with a non-trivial topology in the time domain that can be created for a Bose-Fermi condensate. The resonant driving of a particle in a resonant orbit can be described by an effective time-independent Hamiltonian that describes the motion of a particle close to a resonant orbit between two oscillating mirrors. As an example, we consider a three-band Lieb lattice\textsuperscript{6} on the Möbius strip with a middle flat band. The dynamics of the flat band is governed solely by interactions, which can be easily tuned by periodic changes of scattering length using Feshbach resonance mechanism. This allows us to engineer exotic long-range interactions\textsuperscript{7} and offers a new perspective for studying exotic many-body dynamics.

Single-particle bouncing between two oscillating mirrors

- Hamiltonian in the frame oscillating with the mirrors

\[ H = \frac{p_x^2 + p_y^2}{2m} + V(x,y,t) \quad y \geq 0 \geq x \]

- The mirrors are located around \( x = 0 \) and \( x = -W \)

\[ V(x) = \begin{cases} V_0 & \text{for } x \leq 0 \\ -V_0 & \text{for } x > 0 \end{cases} \]

- All trajectories are periodic

- Third independent integral of motion \( \Theta(x,y,t) = (\theta_1(x,t) - \theta_2(y,t)) \bmod 2\pi \)

- Canonical transformation from \((I_1, I_2, \theta_1, \theta_2)\) to new variables \((I_1, I_2, \theta_1, \theta_2)\) where

\[ I_1 = \text{const} \quad \theta_1 = \text{const} \quad \theta_2 = \text{const} \quad \theta_3 = \Omega_t + \Theta(x,y,t) \]

The wedge for \( f_{\theta} = f_{y-x} \) at \( 0 \geq x \geq 0 \)

- The system is integrable \( \to \) action-angle variables

\[ H_{\theta}(I_1, I_2) = \frac{\Omega_2}{2} I_2^2 + \frac{\Omega_1^2}{2} I_1^2 + \omega_{\theta} I_1 I_2 \]

for \( k_1 \theta_1(x,t) - k_2 \theta_2(y,t) \)

- All trajectories are periodic

- Third independent integral of motion \( I_2 = (k_1 \theta_1 - k_2 \theta_2) \mod 2\pi \)

- Periodic orbit can be described by a single frequency only

- Canonical transformation from \((I_1, I_2, \theta_1, \theta_2)\) to new variables \((I_1, I_2, \theta_1, \theta_2)\)

\[ I_1 = \text{const} \quad \theta_1 = \text{const} \quad \theta_2 = \text{const} \quad \theta_3 = \text{const} + \text{const} \]

The wedge for \( f_{\theta} = f_{y-x} \) at \( 0 \geq x \geq 0 \)

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\[ I_1 = \text{const} \quad \theta_1 = \text{const} \quad \theta_2 = \text{const} \quad \theta_3 = \text{const} + \text{const} \]

Periodically oscillating mirrors

- Resonant driving of a particle \( \omega = \Omega_2(I_1, I_2) \)

- Classical securum approximation

- Canonical transformation to the frame moving along a resonant orbit

- Cartesian coordinates \((x_\perp, \theta_\perp)\) and \((y_\perp, \theta_\perp)\) can be expanded in the Fourier series

\[ x, y = \sum_{n \in \mathbb{Z}} \phi_n(x_\perp, \theta_\perp) e^{i(n \Omega_1 t + \Omega_2 y_\perp)} \]

- All dynamical variables evolve slowly if we choose initial conditions close to the resonant orbits

- Averaging over the fast time variable

- Effective time-independent Hamiltonian that describes the motion of a particle close to a resonant orbit

\[ H_{\theta} = \frac{\Omega_2^2}{2} I_2^2 + \frac{\Omega_1^2}{2} I_1^2 + \omega_{\theta} I_1 I_2 \]

By different shaking protocols of two mirrors \( i \) and \( j \), it is feasible to construct many lattice geometries, just like in optical lattice engineering.

Lattice structures

- Effective Hamiltonian

\[ H_{\theta} = \frac{\Omega_2^2}{2} I_2^2 + \frac{\Omega_1^2}{2} I_1^2 + \omega_{\theta} I_1 I_2 \]

- With \( \Omega_1 = \sqrt{\frac{1}{2} \omega_{\theta}} \)

- For \( j \ll \Omega_1 \ll 1 \), eigenvalues of \( H_{\theta,j} \) form well separated three bands where the central band is flat

Ultra-cold bosonic atoms in the flat band

- Bosons interact via Dirac-delta potential \( g(x) \)

- Many-body Floquet Hamiltonian restricted to the flat band subspace

\[ H = \sum_{n=1}^{N} \int dt \int dx \psi^\dagger_n \left( \hat{H}_0 + \Delta_{\theta} \hat{J}_n \right) \psi_n \]

- \( \Delta_{\theta} = \sum_{n=1}^{N} \hat{H}_n \psi_n \) with the bosonic operators \( \hat{b}_n, \hat{b}_n^\dagger \)

- Control of the contact interactions by changes of scattering length using Feshbach resonance mechanism

\[ \Delta_{\theta} = \sum_{n=1}^{N} \hat{H}_n \psi_n \]

- Wannier states corresponding to the flat band \( w(x,y,t) = w(x,y) e^{i \theta T} \)

Pair tunneling processes

- Hard-core bosons Floquet Hamiltonian

\[ H_{\theta} = \frac{1}{2} \sum_{j \neq j'} \hat{n}_{j} \hat{n}_{j'} + J \sum_{j} \left( \hat{n}_{j} \hat{n}_{j'} + H.c. \right) + \frac{1}{2} \Omega_1 \Omega_2 \]

- Simultaneous tunneling of two particles between four distinct lattice sites \( J = \Omega_1 \Omega_2 \)

Recent neighbour repulsion \( V = J \Omega_1 \Omega_2 \)

References

[1] K. Sacha, Phys. Rep. 5, 10737 (2015).
[2] K. Giergiel, A. Dasgupta, M. Lewenstein, Z. Zakrzewski, and K. Sacha, Eur. Phys. J. D 13, 2039 (2010).
[3] A. Kosior and K. Sacha, Phys. Rev. A 97, 053621 (2018).
[4] K. Giergiel, A. Kosior, and K. Sacha, Phys. Rev. B 99, 220303 (2019).
[5] P. Mateo and K. Sacha, Phys. Rev. A 99, 035620 (2019).
[6] S. Tise, H. Ozawa, T. Ichinose, T. Nishio, S. Nakajima, and Y. Takahashi, Science Advances 1 (2015).
[7] K. Giergiel, A. Miranszewska, and K. Sacha, Phys. Rev. Lett. 120, 150401 (2018).
Resonating valence bond realization of spin-1 non-Abelian chiral spin liquid on the torus

Hua-Chen Zhang
Resonating valence bond realization of spin-1 non-Abelian chiral spin liquid on the torus

Hua-Chen Zhang @
IOP CAS & TU Dresden
23 Feb 2021, Benasque SCS
We propose resonating valence bond (RVB) wave functions for a spin-1 lattice system on the torus that realize a non-Abelian chiral spin liquid.

These wave functions are shown to be equivalent to chiral correlation functions in a certain conformal field theory (CFT) and identified to be a lattice analogue of the bosonic Moore-Read state at unit filling.

The topological order of this system is revealed by explicit construction of the topologically degenerate ground states and analytical computation of their modular matrices.
Simulation of three-dimensional quantum systems with projected entangled-pair states

Patrick Vlaar
Simulation of three-dimensional quantum systems with projected entangled-pair states

Patrick Vlaar & Philippe Corboz
arXiv:2102.06715
Simulation of three-dimensional quantum systems with projected entangled-pair states

• Tensor network techniques very successful in 1D and 2D, however applications in 3D are limited

• We present two techniques
  • Cluster contraction
  • Full contraction

• We expect this work to be an important step towards making iPEPS a promising tool to study open problems in 3D
Solving frustrated Ising models using tensor networks

Bram Vanhecke
Solving frustrated Ising models using tensor networks

Bram Vanhecke, Jeanne Colbois, Laurens Vanderstrecten, Frank Verstraete, Frédéric Mila
Phys. Rev. Research 3, 013041 – Published 13 January 2021

|                  | AF-Ising on kagome | AF-Ising on triangular |
|------------------|--------------------|------------------------|
| MPS              | 0.5018331646 (D = 10) | 0.3230659407 (D = 250) |
| exact            | 0.5018331646        | 0.3230659669           |

Spurious cluster configurations
Convex sets, and linear programming: $A\tilde{x} \leq \tilde{B}$
String order parameters for symmetry fractionalization in an enriched toric code

Mohsin Iqbal
String order parameters for symmetry fractionalization in an enriched toric code

José Garre-Rubio, Mohsin Iqbal, David T. Stephen

arXiv:2011.02981

SCS Benasque-2021
**Goal**

*Construct SOP for characterizing the symmetry fractionalization pattern of the anyons: detect the SET phase*

We start from TC on edges decoupled from ferromagnet on vertices

$$H_{SET} = -\sum_{v \in V} A_v - \sum_{f \in F} \tilde{B}_f - \sum_{v \in V} C_v \frac{1 + A_v}{2}$$

$$\tilde{H}_{TC} = H_{TC} - \sum_{v \in V} X_v$$

We end in a decorated TC with cluster states

The charge fractionalizes TRS, BC inversion and the on-site symmetry $\mathbb{Z}_2 \times \mathbb{Z}_2$

We generalize the SOP of [1] beyond PEPS and RGFP to measure the SF class of the charge.

$$\Lambda[a,b] = \frac{\langle \Lambda[a,b] \rangle}{\langle \Lambda[0,0] \rangle}$$

[1] J. Garre-Rubio & S. Iblisdir New Journal of Physics 21, 113016 (2019)
**Results**

Test the SOP in the Hamiltonian interpolation

\[ \lambda \tilde{H}_{TC} + (1 - \lambda) H_{SET} \]

We observe SSB because of the condensation of the anyon that fractionalizes the symmetry (charge vs flux)

Phase diagram under magnetic fields

\[ H_{SET} - h_e^X \sum_e Z_e - h_e^Z \sum_e X_e \]

We observe SSB because of the condensation of the anyon that fractionalizes the symmetry (charge vs flux)

The phase diagram changes from the one of the TC: infinite line between trivial (topological) phases!
The SYK model from strained honeycomb irradiates: A case study

Mikael Fremling
The SYK model from strained honeycomb iridates

The dream

Sachdev-Ye-Kitaev

SYK

Strained Kitaev Honecomb

$S_i^y S_j^y$

$S_i^z S_j^z$

$S_i^x S_j^x$

$H_3LiIr_2O_6$ Iridates

Mikael Fremling

Utrecht University

Entanglement in Strongly Correlated Systems - Benasque - February 2021
Random hopping elements in a flat band

\[ H_{\text{SYK}} = \sum_{i,j,k,l} J_{i,j,k,l} \gamma_i \gamma_j \gamma_j \gamma_k \]

\[ H_{\text{Strain}} = \sum_{n_1,n_2;m_3,m_4} J_{n_1,n_2;m_3,m_4} \gamma_{n_1}^A \gamma_{n_2}^A \gamma_{m_3}^B \gamma_{m_4}^B \]
Variational wave functions for spin-phonon models

F. Ferrari
Variational wave functions for spin-phonon models

Francesco Ferrari, Federico Becca, Roser Valentí

spin liquid

magnetoelastic coupling

\[ J[1 + g(X_1 - X_2)] \mathbf{S}_1 \cdot \mathbf{S}_2 \]

quantum phonons

\[ \frac{\omega}{2}(P^2 + X^2) \]

valence-bond order

variational Ansätze

\[ |\Psi_{\text{spin-phon}}\rangle \]

Monte Carlo sampling