Title: Preparing Critical and Thermofield Double States on a Quantum Computer

Speakers: Timothy Hsieh

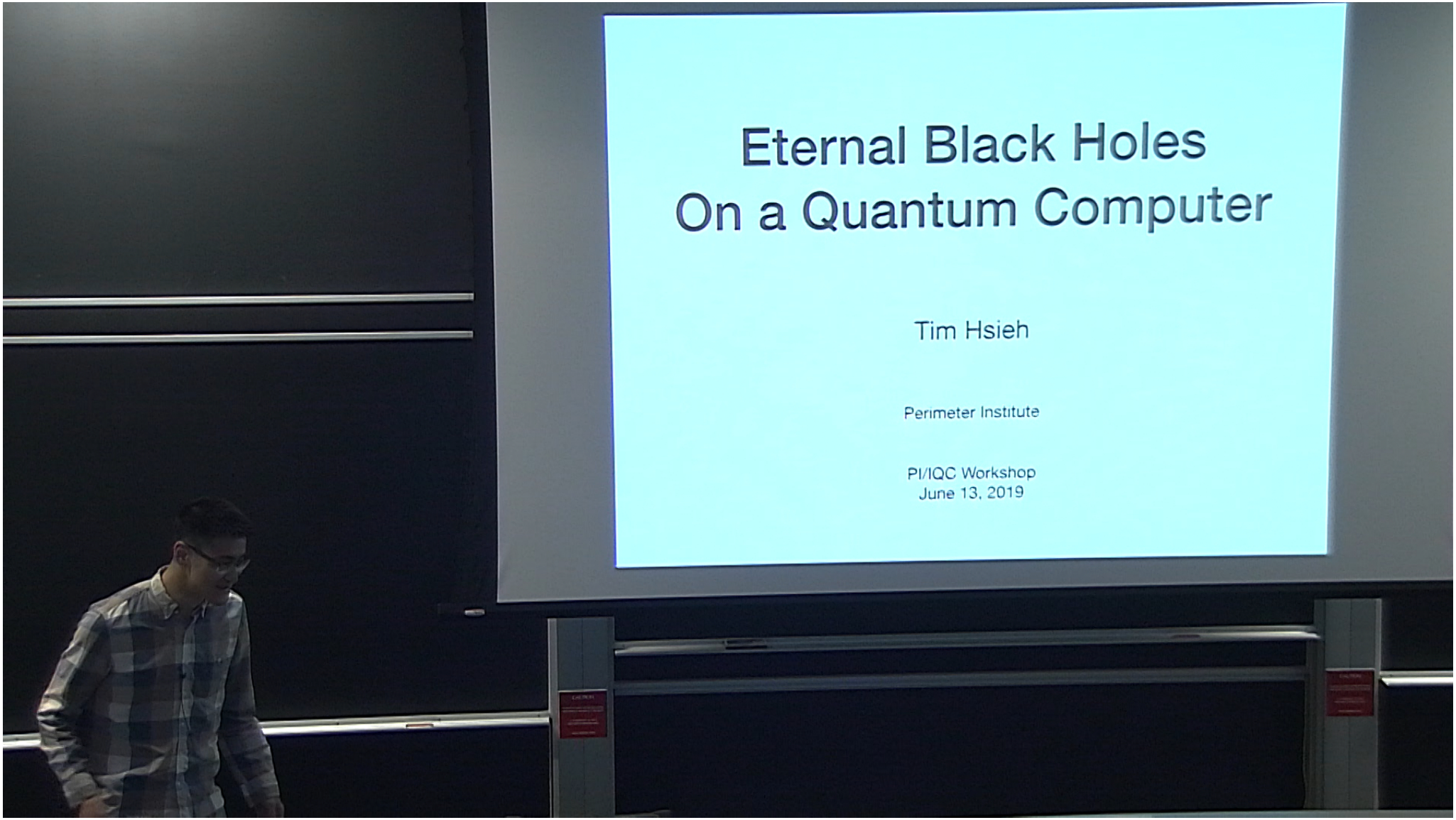
Collection: Many-Body States and Dynamics Workshop II

Date: June 13, 2019 - 9:45 AM

URL: http://pirsa.org/19060028

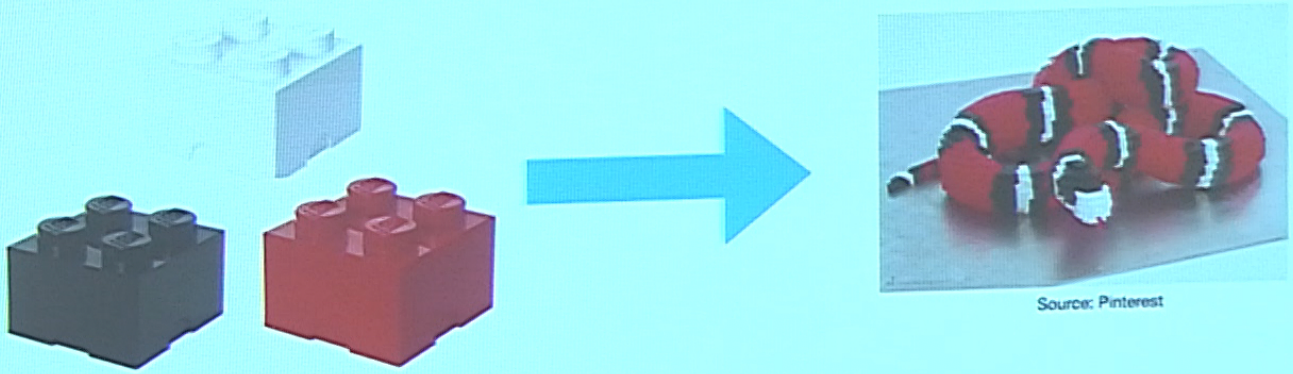
Abstract: I will present an efficient variational approach for preparing highly entangled pure states as well as thermofield double states on a quantum computer. The latter, in addition to being of interest in the holographic correspondence, enables an alternative approach for simulating thermal states without an external heat bath.


Tim Hsieh


Eternal Black Holes
On a Quantum Computer
Tim Hsieh
Perimeter Institute
PI/IQC Workshop
June 13, 2019

Main Goal

General protocols for preparing nontrivial quantum states on near-term platforms

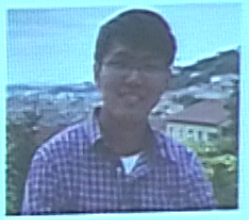


Source: Pinterest

Overview

Preparation of non-trivial quantum states

WWH and TH, SciPost Phys. 6, 029 (2019)



Wen Wei Ho (Harvard)

Thermal quantum simulation

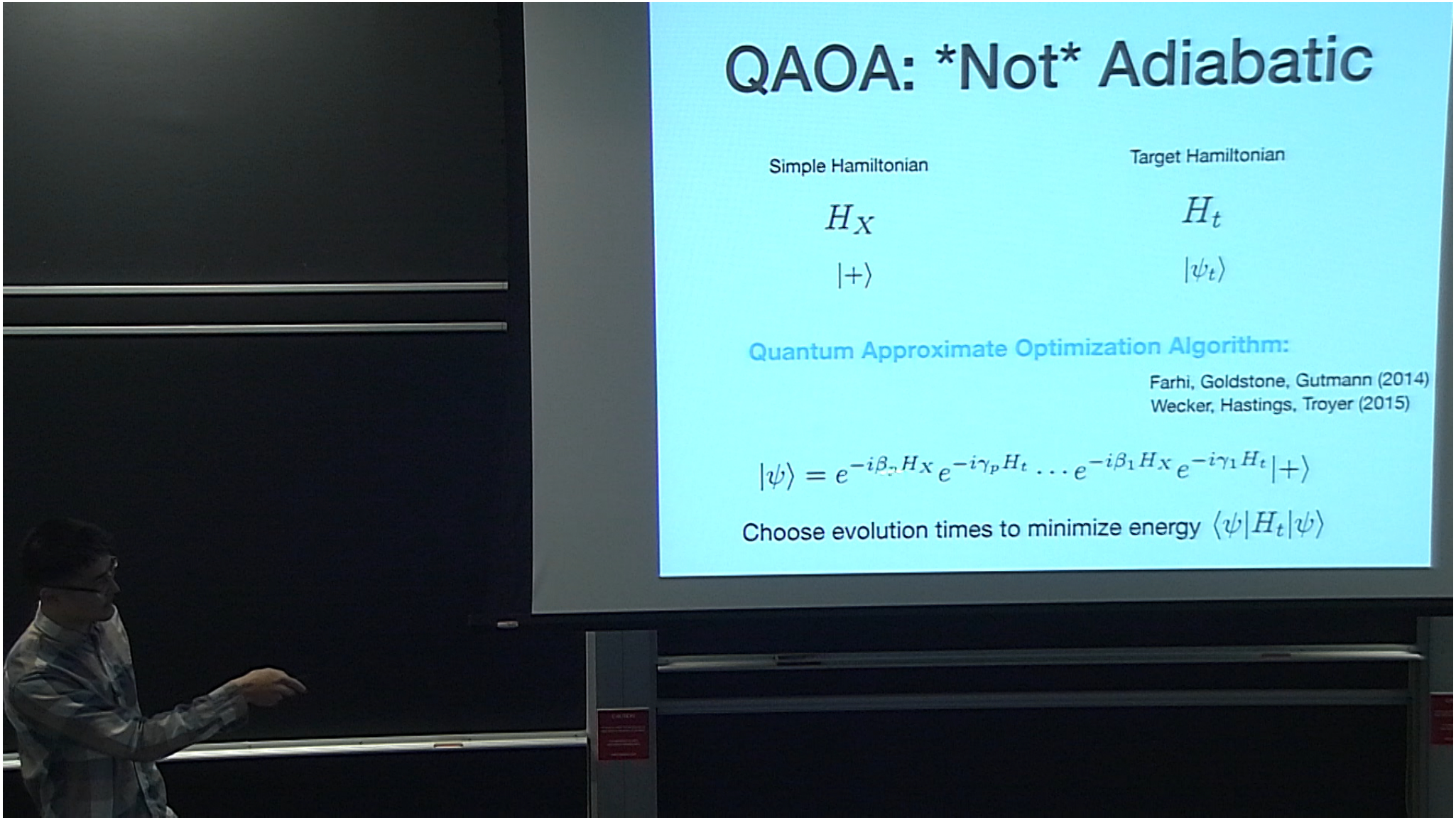
JW and TH, arXiv:1811.11756 (2018)

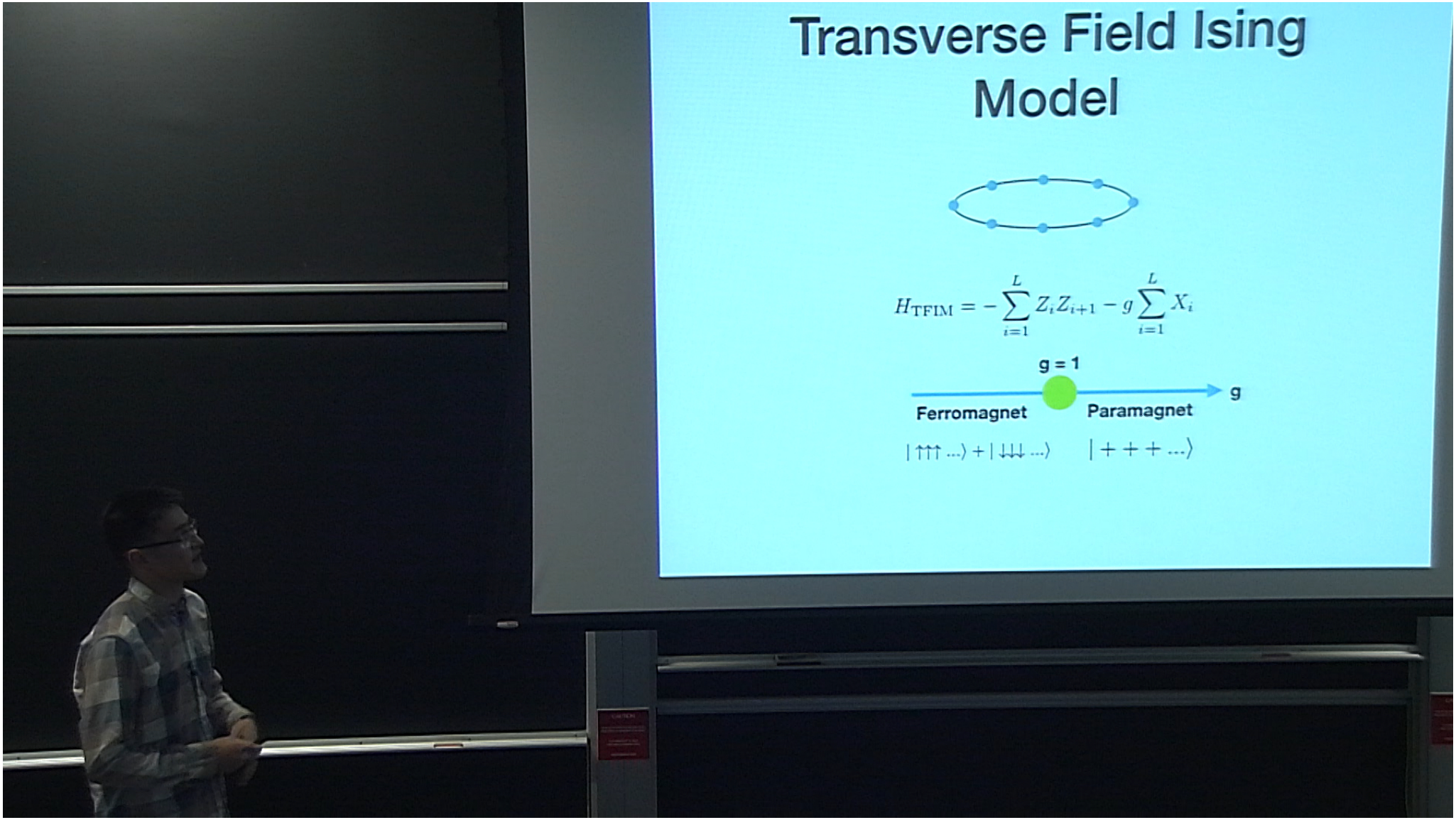
Jingxiang Wu (Perimeter)

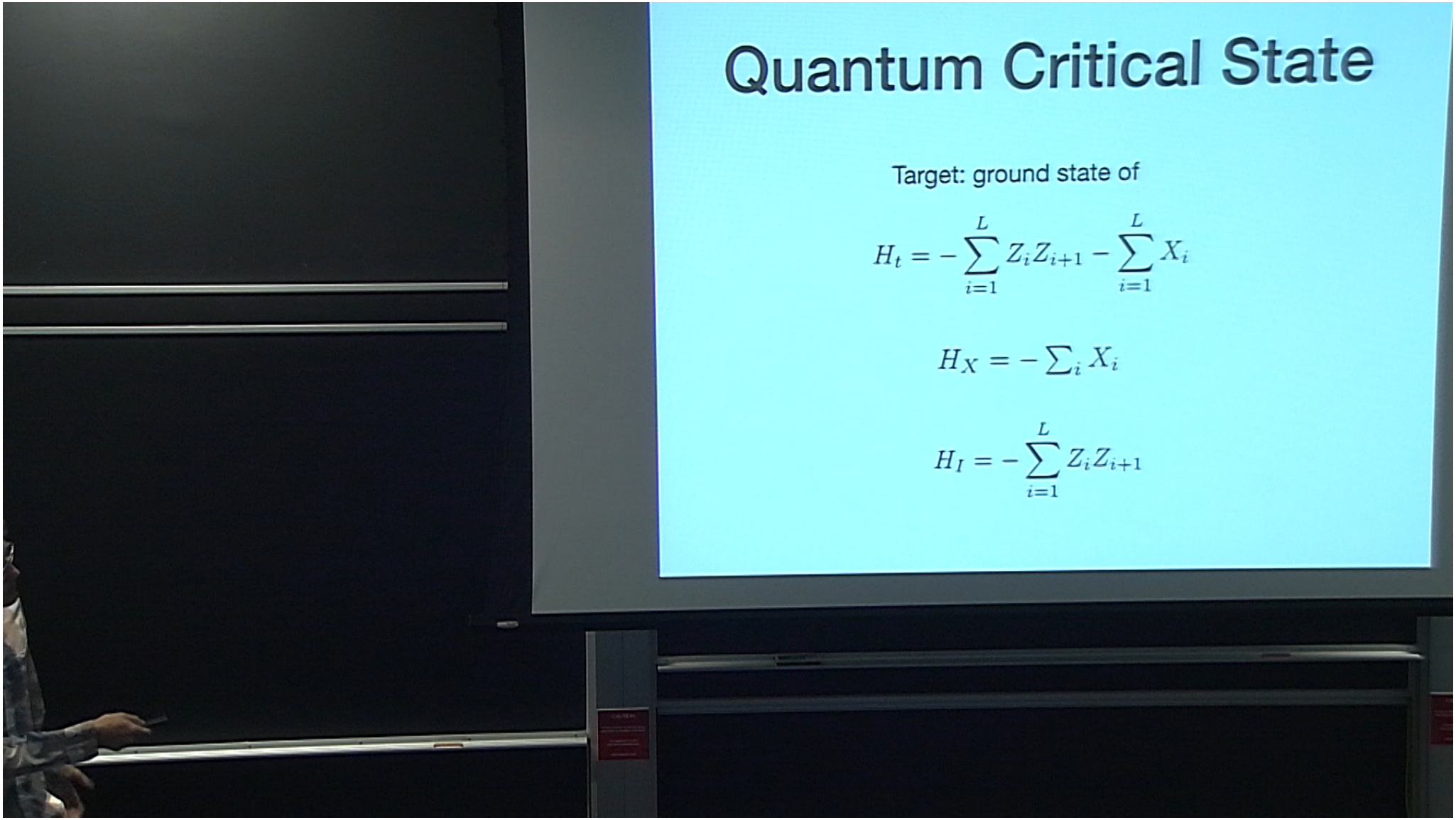
Experiment: arXiv:1906.02699 (last week)

Variational Generation of Thermofield Double States and Critical Ground States with a Quantum Computer

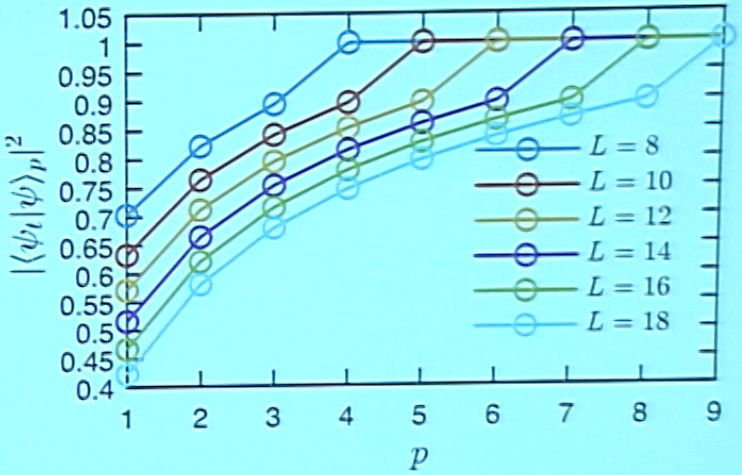
D. Zhu[1], S. Johri[2], N. M. Linke[1], K. A. Landsman[1], N. H. Nguyen[1], C. H. Alderete[1], A. Y. Matsuura[2], T. H. Hsieh[3], and C. Monroe[1]


QAOA: *Not* Adiabatic
Simple Hamiltonian
H_X
$|+\rangle$
Target Hamiltonian
H_t
$|\psi_t\rangle$
Quantum Approximate Optimization Algorithm:
Farhi, Goldstone, Gutmann (2014)
Wecker, Hastings, Troyer (2015)
$|\psi\rangle = e^{-i\beta_p H_X} e^{-i\gamma_p H_t} \cdots e^{-i\beta_1 H_X} e^{-i\gamma_1 H_t} |+\rangle$
Choose evolution times to minimize energy $\langle\psi|H_t|\psi\rangle$

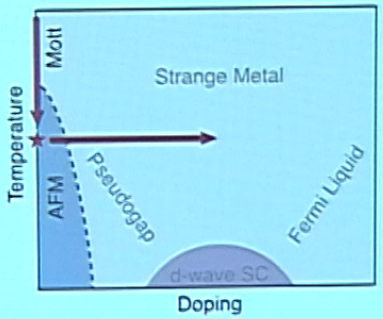

Transverse Field Ising Model
$H_{\mathrm{TFIM}} = -\sum_{i=1}^{L} Z_i Z_{i+1} - g \sum_{i=1}^{L} X_i$
g = 1
g
Ferromagnet
Paramagnet
$|\uparrow\uparrow\uparrow \ldots\rangle + |\downarrow\downarrow\downarrow \ldots\rangle$
$|+++\ldots\rangle$


Quantum Critical State
Target: ground state of
$H_t = -\sum_{i=1}^{L} Z_i Z_{i+1} - \sum_{i=1}^{L} X_i$
$H_X = -\sum_i X_i$
$H_I = -\sum_{i=1}^{L} Z_i Z_{i+1}$

Quantum Critical State Preparation



Thermal Quantum Simulation



A. Mazurenko et.al., Nature (2017)

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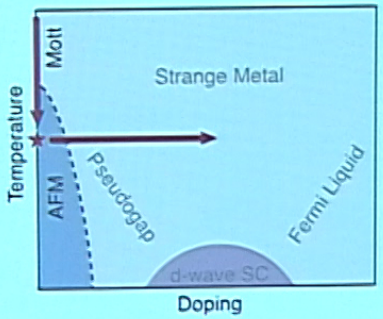

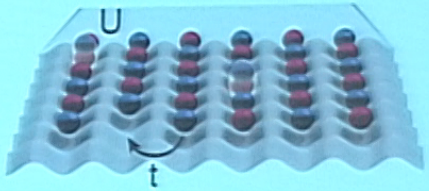

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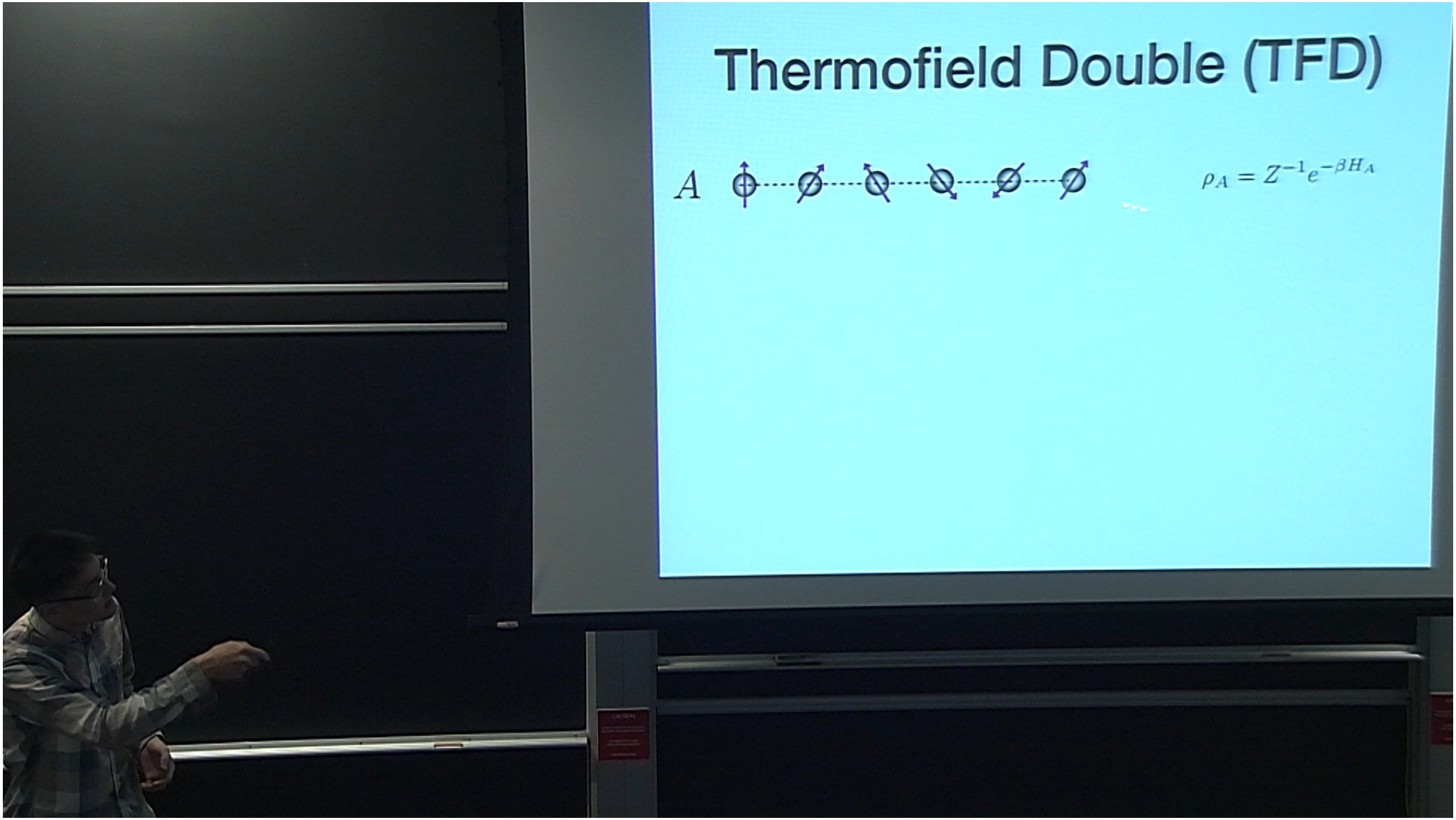
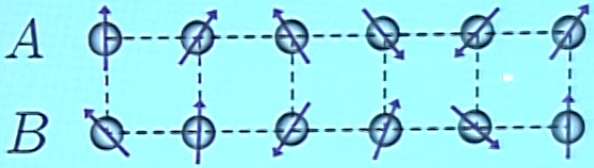

Thermofield Double (TFD)
A
$\rho_A = Z^{-1} e^{-\beta H_A}$

Thermofield Double (TFD)



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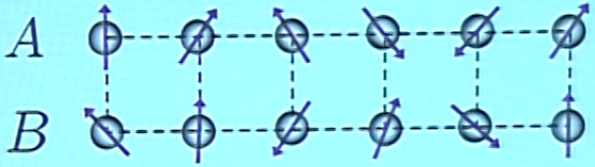
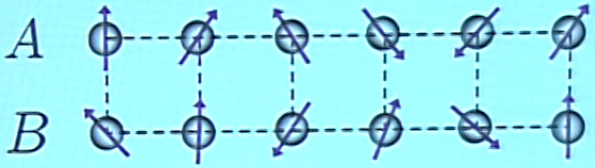


$$\rho_A = Z^{-1} e^{-\beta H_A}$$

$$|\mathrm{TFD}(\beta)\rangle = \frac{1}{\sqrt{Z}} \sum_n e^{-\beta E_n/2} |n\rangle_A |\tilde{n}\rangle_B$$

Thermofield Double (TFD)



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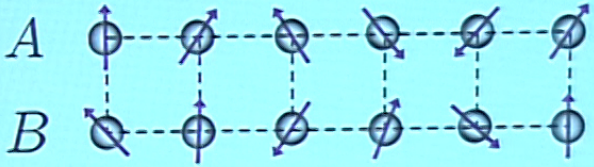

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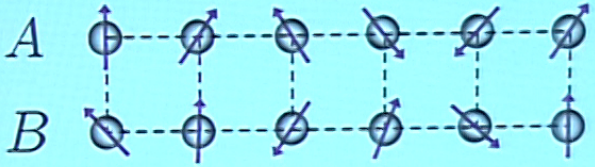

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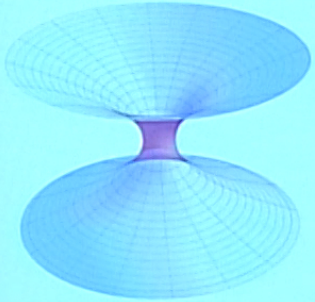

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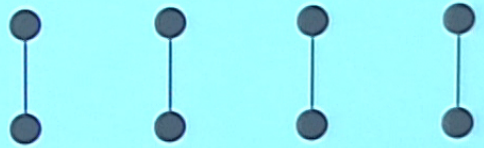
Variational Ansatz

$$|\psi(\vec{\alpha},\vec{\gamma})\rangle_p = \prod_{i=1}^{p} e^{i\alpha_i H_{AB}} e^{i\gamma_i (H_A+H_B)/2} |\mathrm{TFD}(0)\rangle$$

Entangler; Has $|\mathrm{TFD}(0)\rangle$ as ground state

"dual" of H_A (usually the same)



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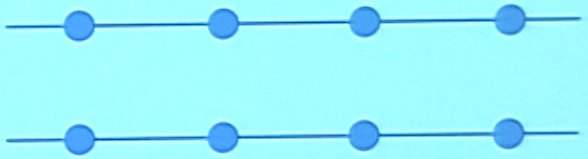
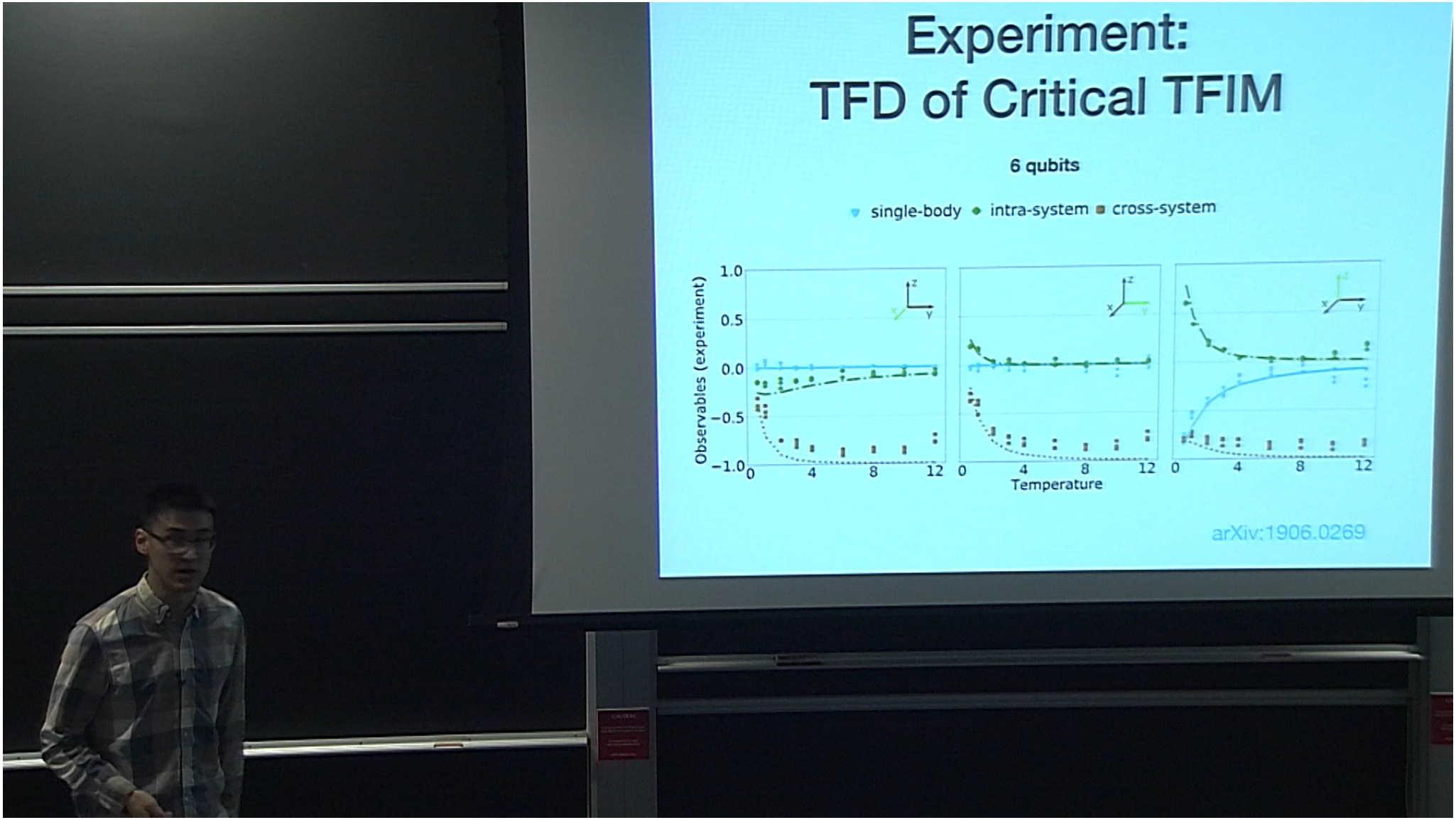
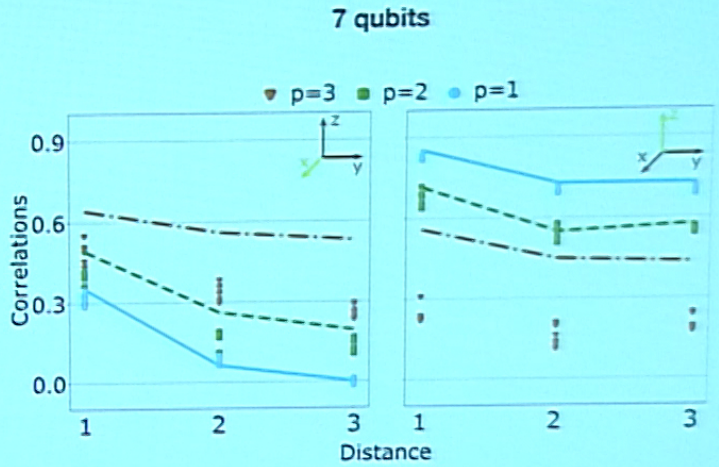



Experiment:
TFD of Critical TFIM
6 qubits
single-body
intra-system
cross-system
Observables (experiment)
1.0
0.5
0.0
−0.5
−1.0
0
4
8
12
Temperature
arXiv:1906.0269

Experiment:
TFIM Critical Ground State



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