



# QCC MTY IE

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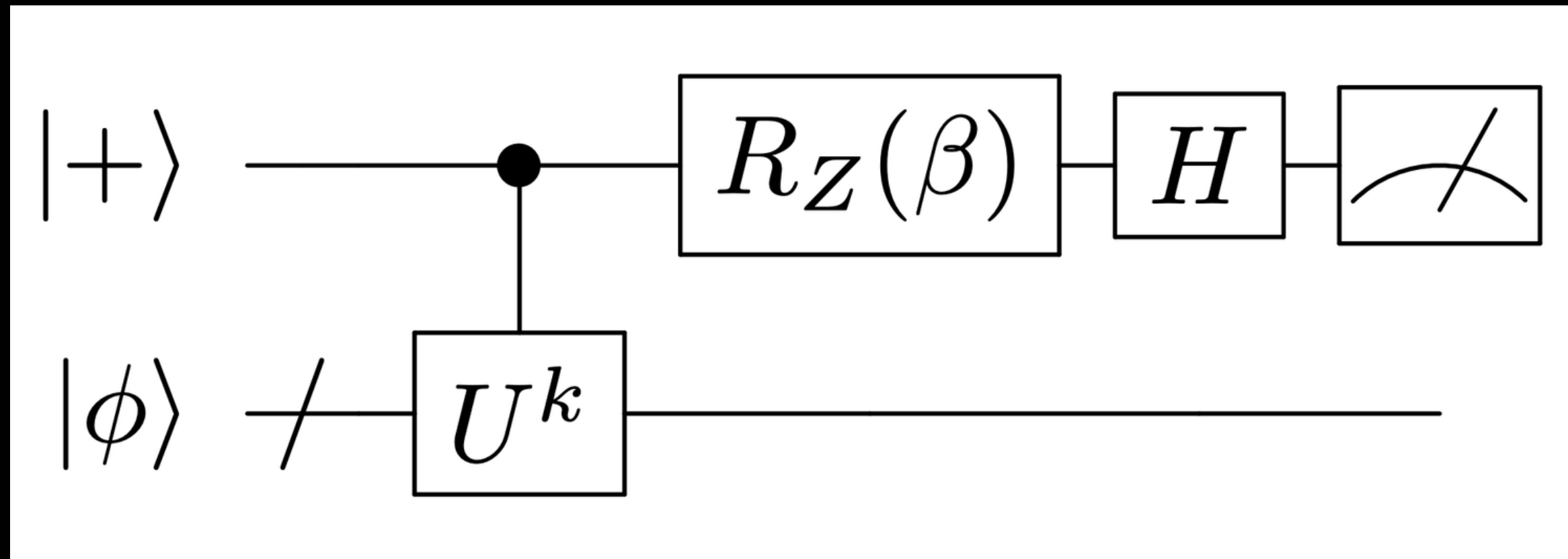
Santiago Copado

Quantum Phase Estimation

4th Feb 2024

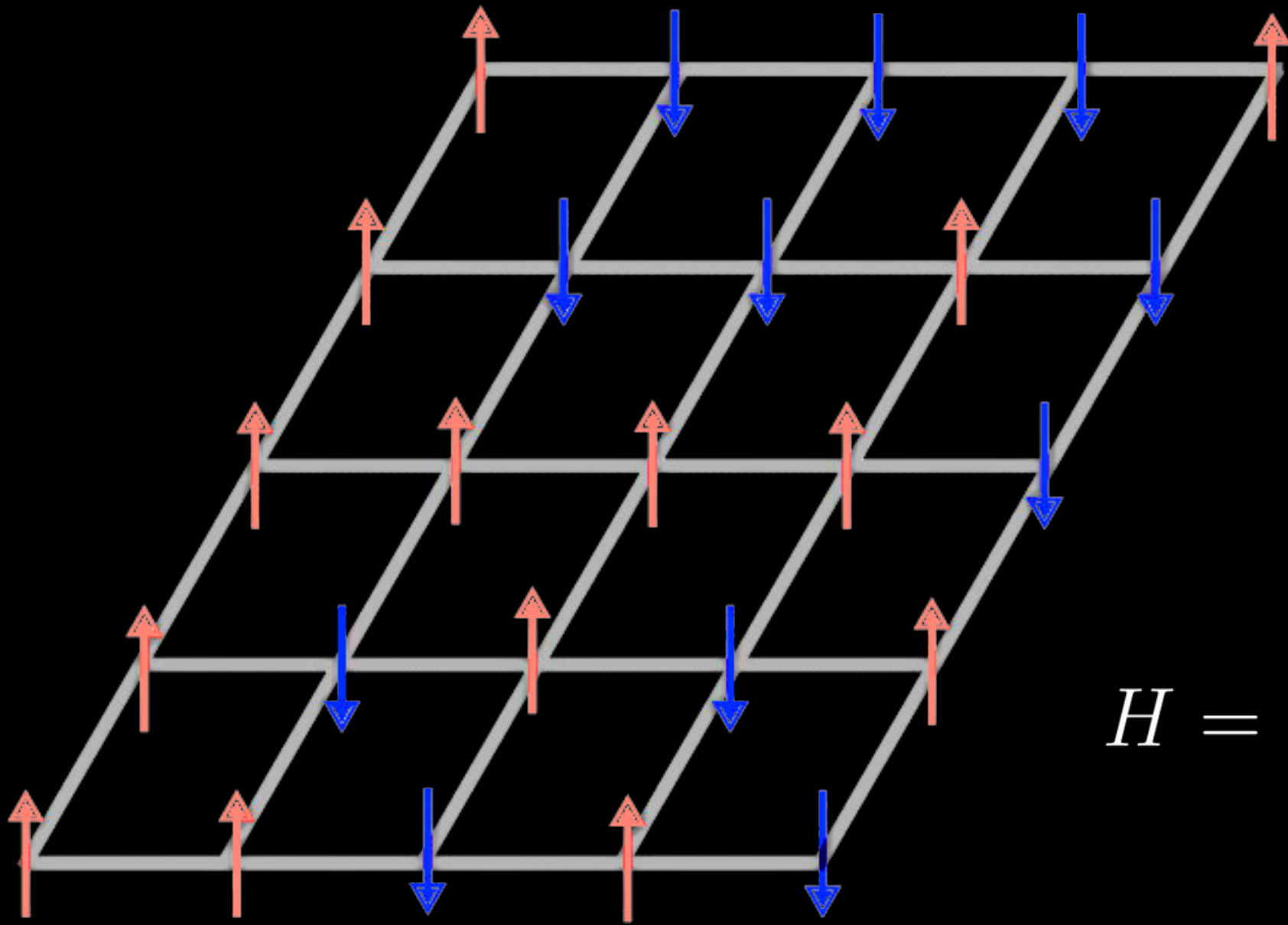


# Background



Classic and Bayesian QPE

# 2D ISING Model

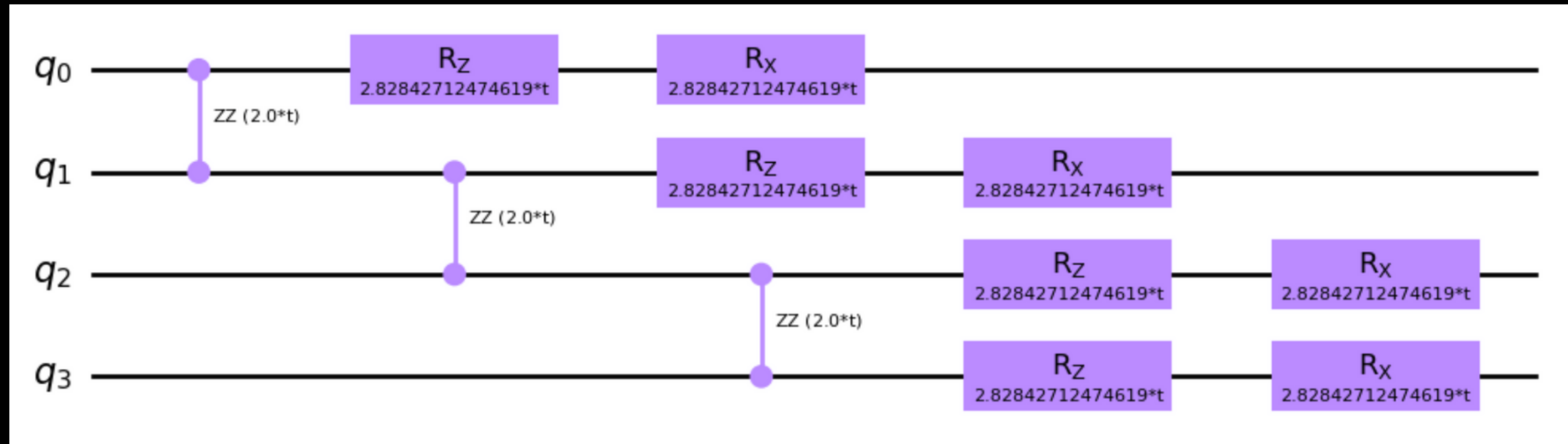


Finding the true global ground state!

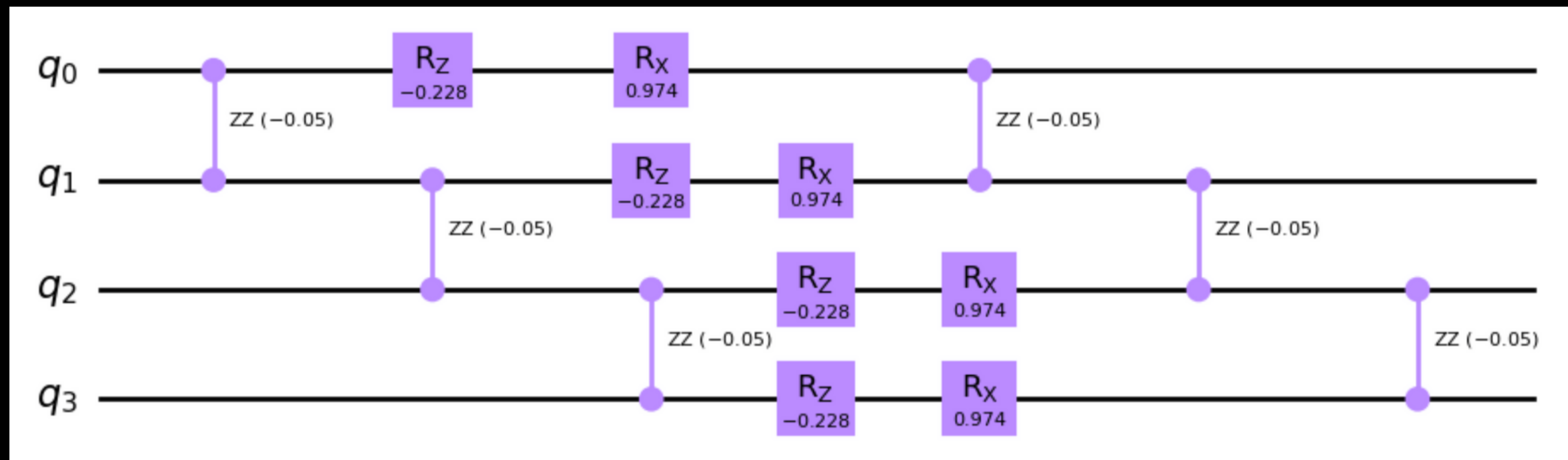
$$H = -J \sum_{i=0}^{L-2} \sigma_i \sigma_{i+1} - h \sum_{i=0}^{L-1} \sigma_i$$

$$H = -J \sum_{i=0}^{L-2} Z_i Z_{i+1} - h \sum_{i=0}^{L-1} (\sin \alpha Z_i + \cos \alpha X_i)$$

# Trotter step with Lie-Trotter



# Trotter step with Suzuki Trotter (2nd order)



# Evidence

## Optimizing quantum phase estimation for the simulation of Hamiltonian eigenstates

P. M. Q. Cruz<sup>1,2,\*</sup>, G. Catarina<sup>1</sup>, R. Gautier<sup>1,3</sup>, J. Fernández-Rossier<sup>1,†</sup>

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(Dated: August 3, 2020)

We revisit quantum phase estimation algorithms for the purpose of obtaining the energy levels of many-body Hamiltonians and pay particular attention to the statistical analysis of their outputs. We introduce the mean phase direction of the parent distribution associated with eigenstate inputs as a new post-processing tool. By connecting it with the unknown phase, we find that if used as its direct estimator, it exceeds the accuracy of the standard majority rule using one less bit of resolution, making evident that it can also be inverted to provide unbiased estimation. Moreover, we show how to directly use this quantity to accurately find the energy levels when the initialized state is an eigenstate of the simulated propagator during the whole time evolution, which allows for shallower algorithms. We then use IBM Q hardware to carry out the digital quantum simulation of three toy models: a two-level system, a two-spin Ising model and a two-site Hubbard model at half-filling. Methodologies are provided to implement Trotterization and reduce the variability of results in noisy intermediate scale quantum computers.

## Exact Ising model simulation on a quantum computer

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December 20, 2018

## Completeness of the classical 2D Ising model and universal quantum computation

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(Dated: October 22, 2018)

We prove that the 2D Ising model is *complete* in the sense that the partition function of any classical  $q$ -state spin model (on an arbitrary graph) can be expressed as a special instance of the partition function of a 2D Ising model with complex inhomogeneous couplings and external fields. In the case where the original model is an Ising or Potts-type model, we find that the corresponding 2D square lattice requires only polynomially more spins w.r.t the original one, and we give a constructive method to map such models to the 2D Ising model. For more general models the overhead in system size may be exponential. The results are established by connecting classical spin models with measurement-based quantum computation and invoking the universality of the 2D cluster states.

PACS numbers: 03.67.-a, 03.67.Lx, 75.10.Hk, 75.10.Pq, 02.70.-c

# Results

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# Bayesian Model

