Title: Simulating an expanding universe on Google's Bristlecone

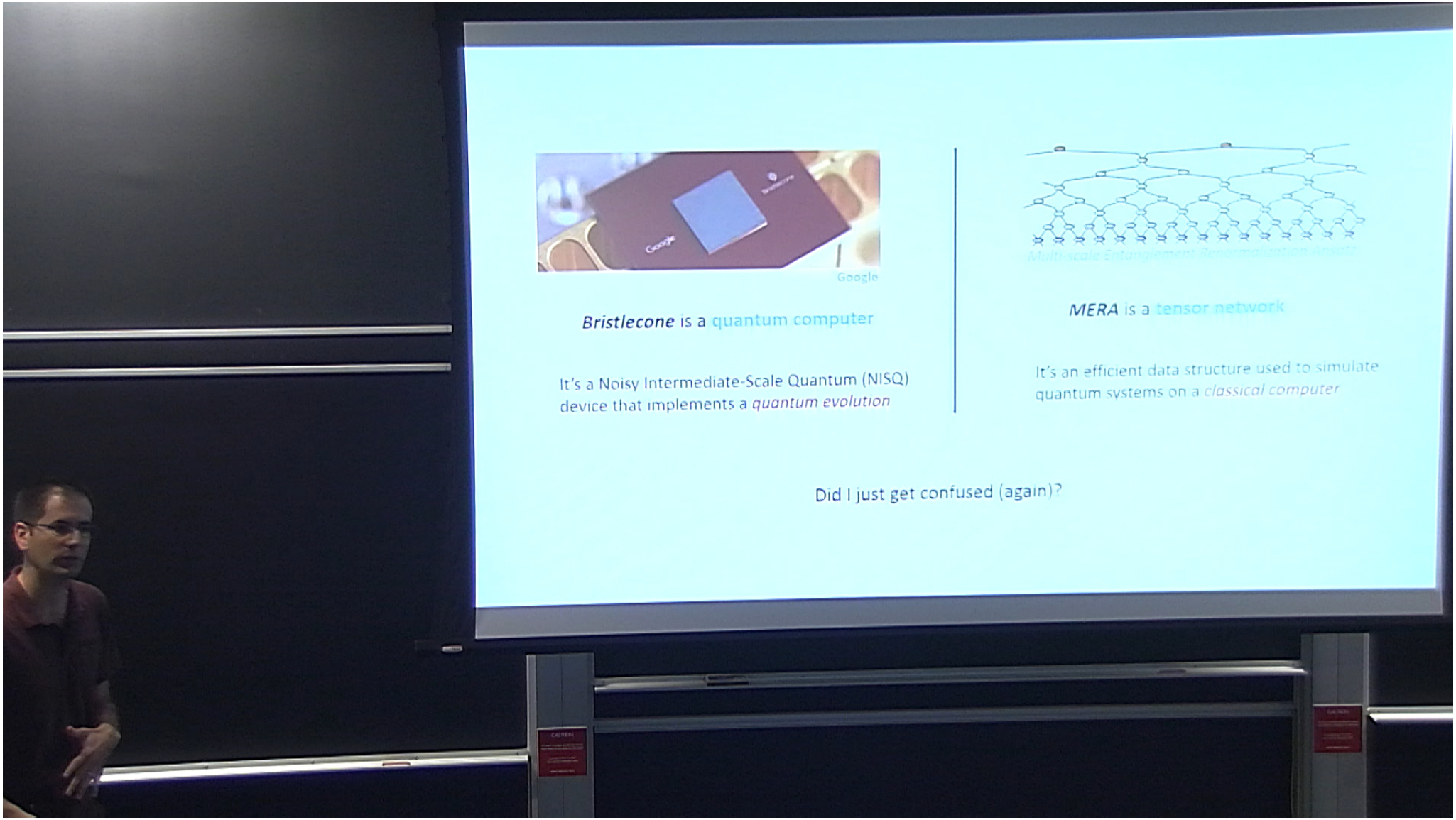
Speakers: Guifre Vidal

Collection: Many-Body States and Dynamics Workshop II

Date: June 13, 2019 - 9:30 AM

URL: http://pirsa.org/19060027

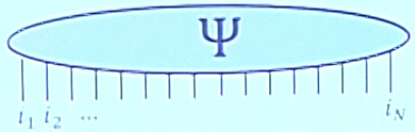
Abstract: I will describe a proposal to simulate MERA on Google's 72 qubit NISQ device known as Bristlecone, and explain how it can be the basis for simulating inflation in an early universe. Other applications of this proposal include benchmarking of the NISQ device, hybrid classical quantum optimizations and quantum machine learning.


Google
Bristlecone is a quantum computer
It's a Noisy Intermediate-Scale Quantum (NISQ) device that implements a quantum evolution
MERA is a tensor network
It's an efficient data structure used to simulate quantum systems on a classical computer
Did I just get confused (again)?

MERA is a tensor network

wave-function of N qubits

$$|\Psi\rangle = \sum_{i_1,i_2,\cdots,i_N} \Psi_{i_1 i_2 \cdots i_N} |i_1 i_2 \cdots i_N\rangle$$



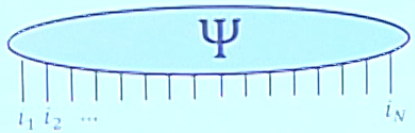
2^N
parameters

inefficient

MERA is a tensor network

wave-function of N qubits

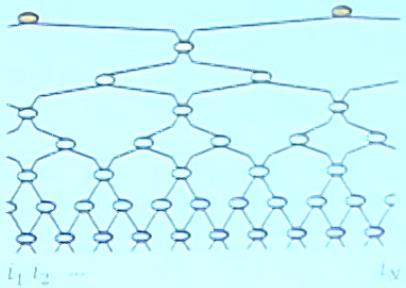
$$|\Psi\rangle = \sum_{i_1,i_2,\cdots,i_N} \Psi_{i_1 i_2 \cdots i_N} |i_1 i_2 \cdots i_N\rangle$$

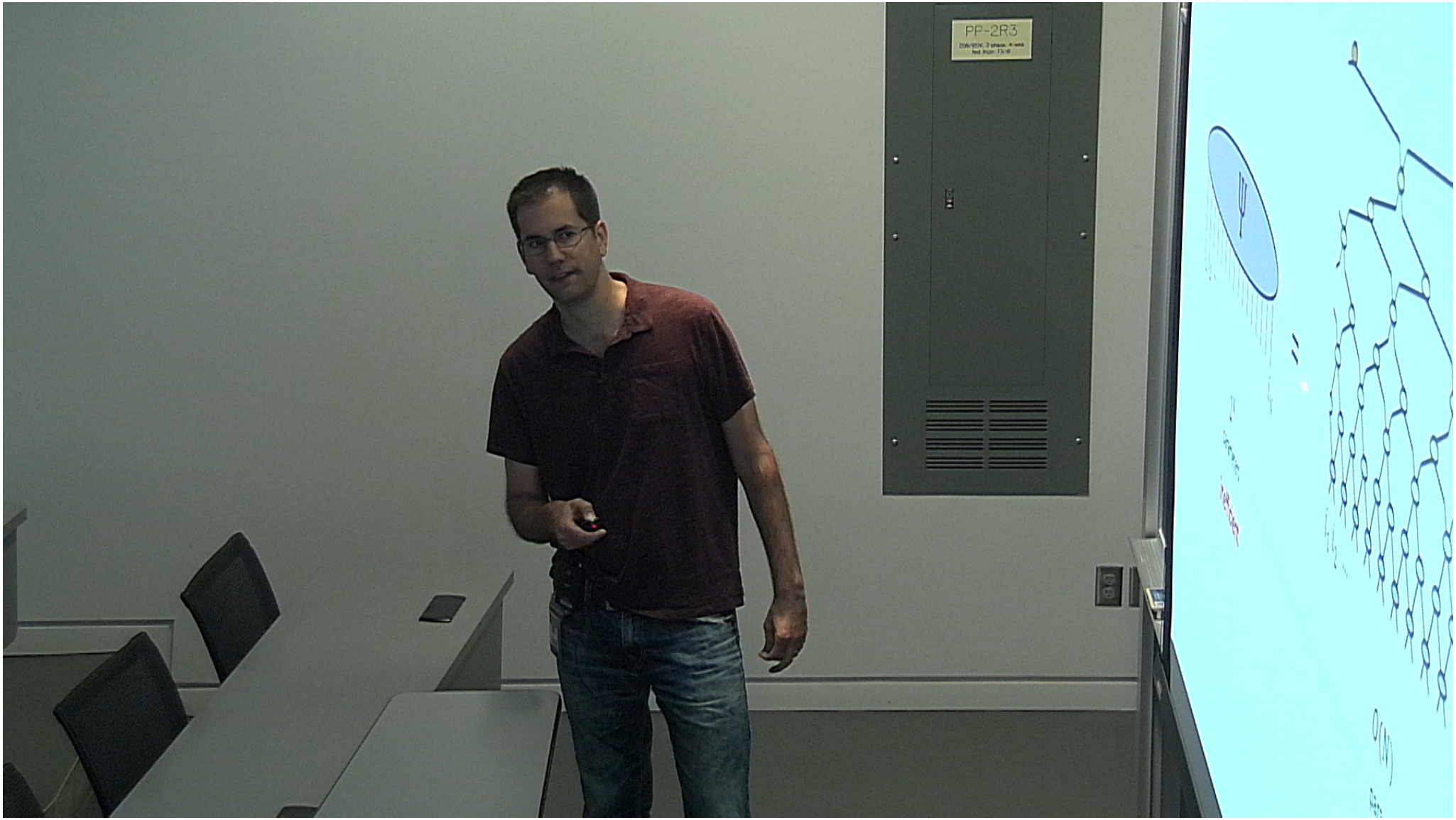


2^N
parameters

inefficient

=

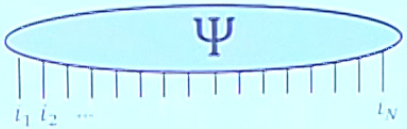



PP-2R3

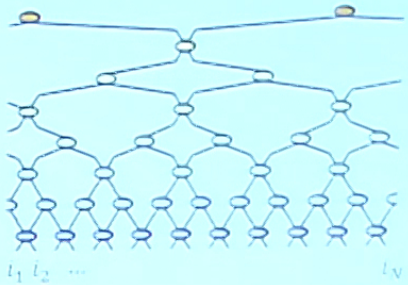
MERA is a tensor network

wave-function of N qubits

$$|\Psi\rangle = \sum_{i_1, i_2, \cdots, i_N} \Psi_{i_1 i_2 \cdots i_N} |i_1 i_2 \cdots i_N\rangle$$



=



2^N
parameters

inefficient

$O(N)$
parameters

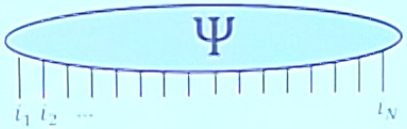
efficient

- we can efficiently simulate quantum computers with a classical computer!

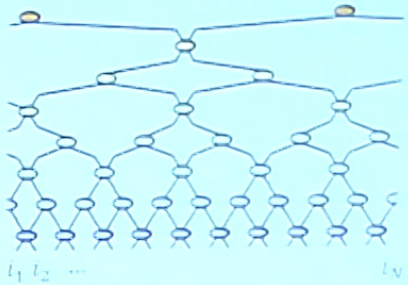
MERA is a tensor network

wave-function of N qubits

$$|\Psi\rangle = \sum_{i_1, i_2, \cdots, i_N} \Psi_{i_1 i_2 \cdots i_N} |i_1 i_2 \cdots i_N\rangle$$



=



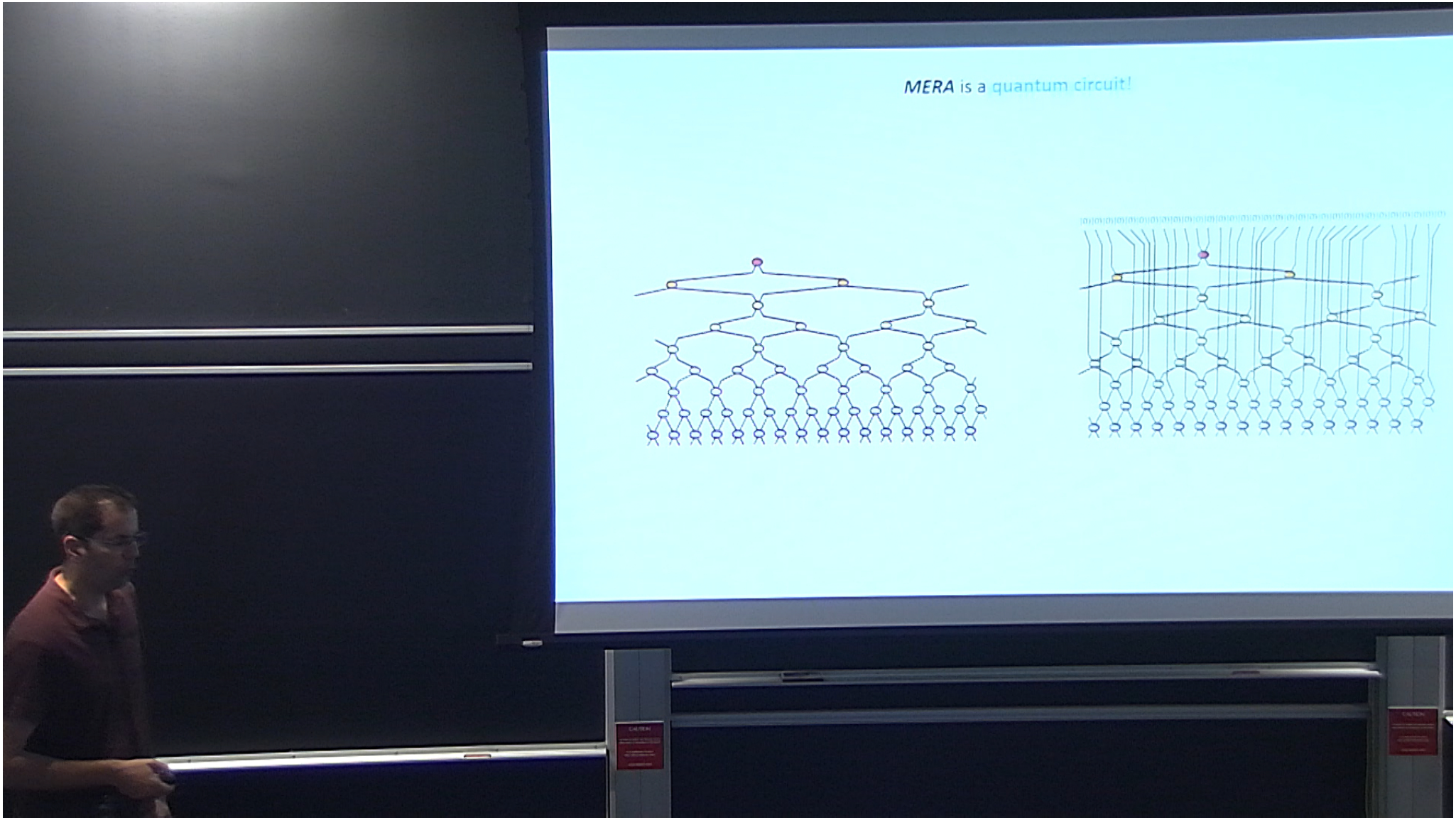
2^N
parameters

inefficient

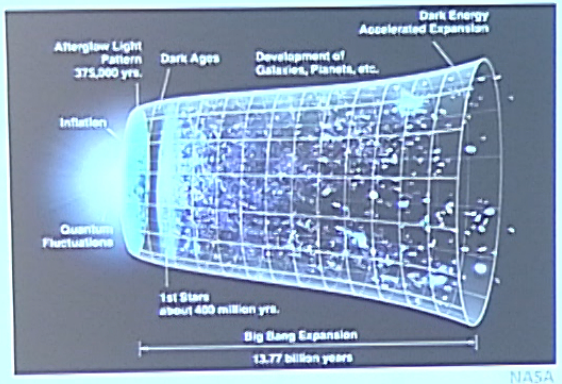
$O(N)$
parameters

efficient

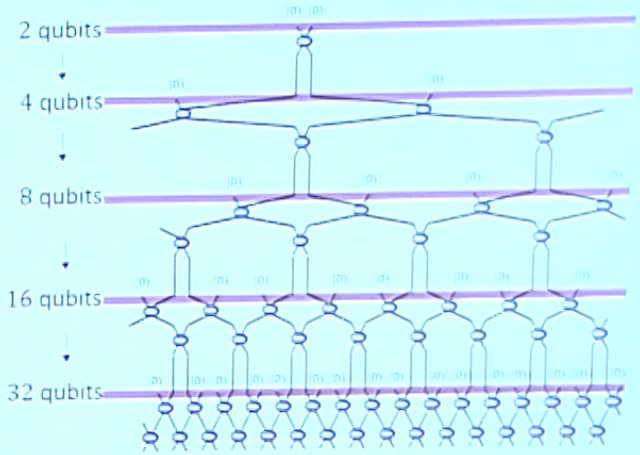
- we can efficiently simulate quantum computers with a classical computer!
- *only* when the many-body wave-function is moderately entangled

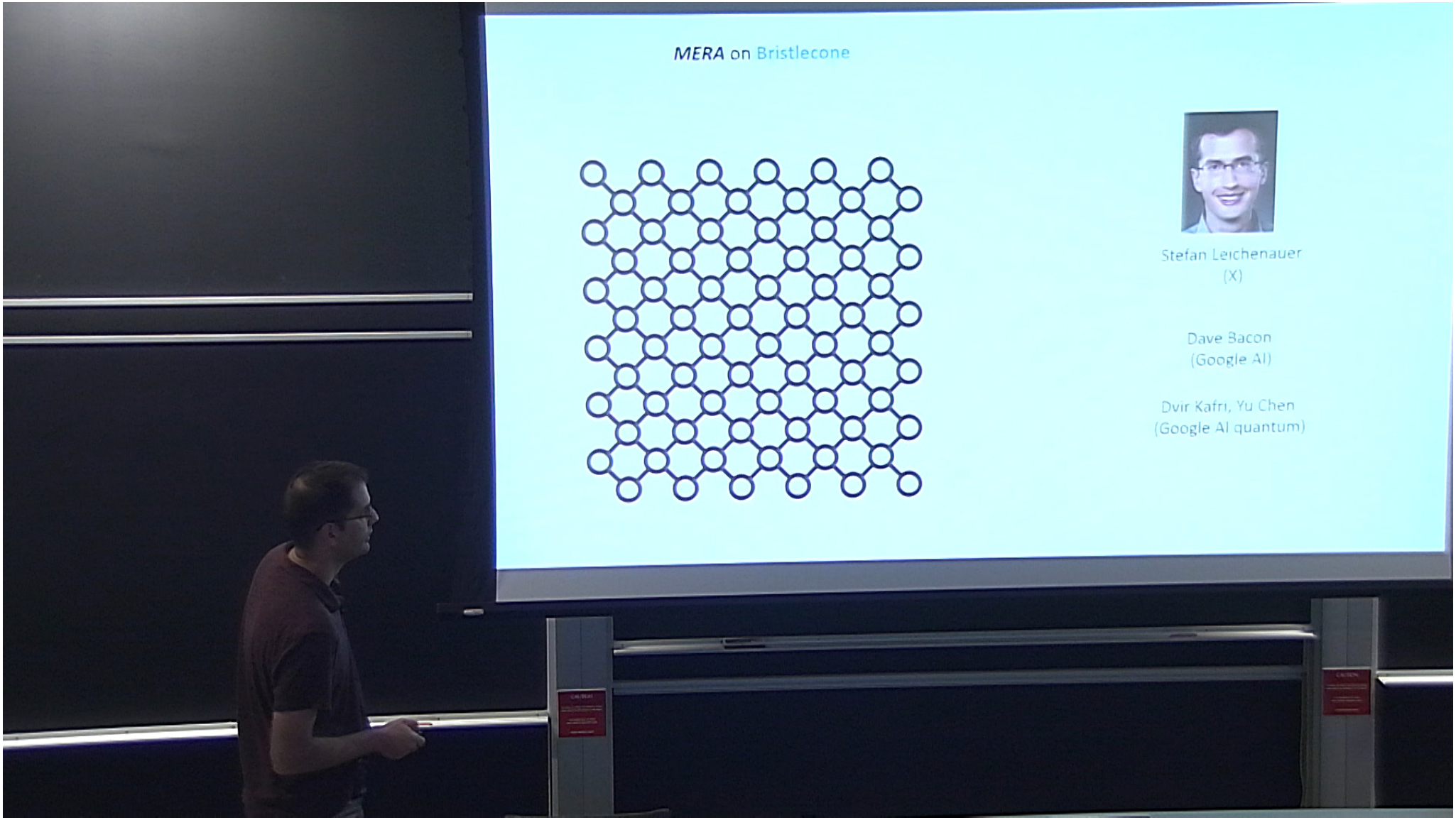

MERA is a quantum circuit!

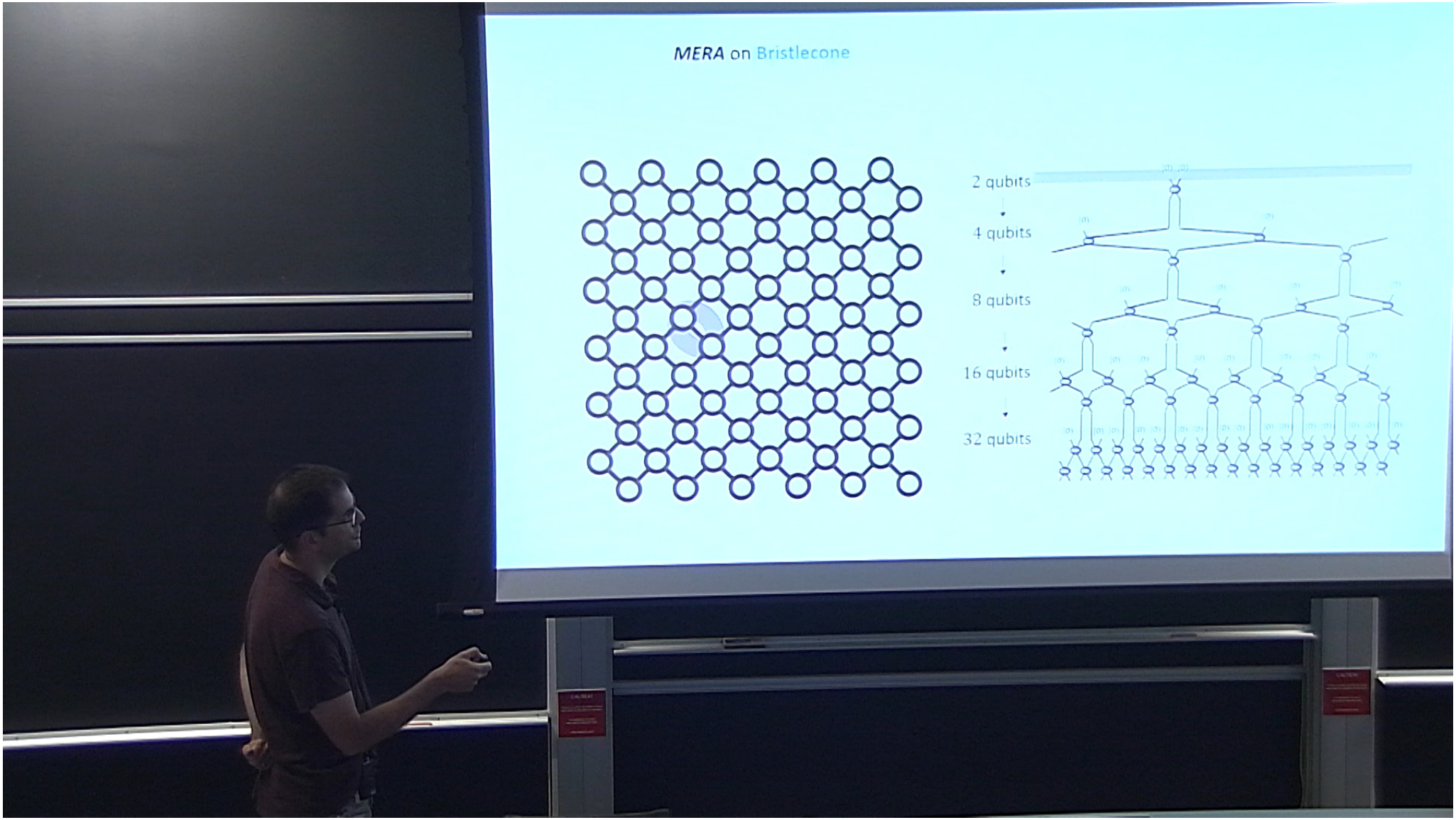
MERA simulates an expanding universe

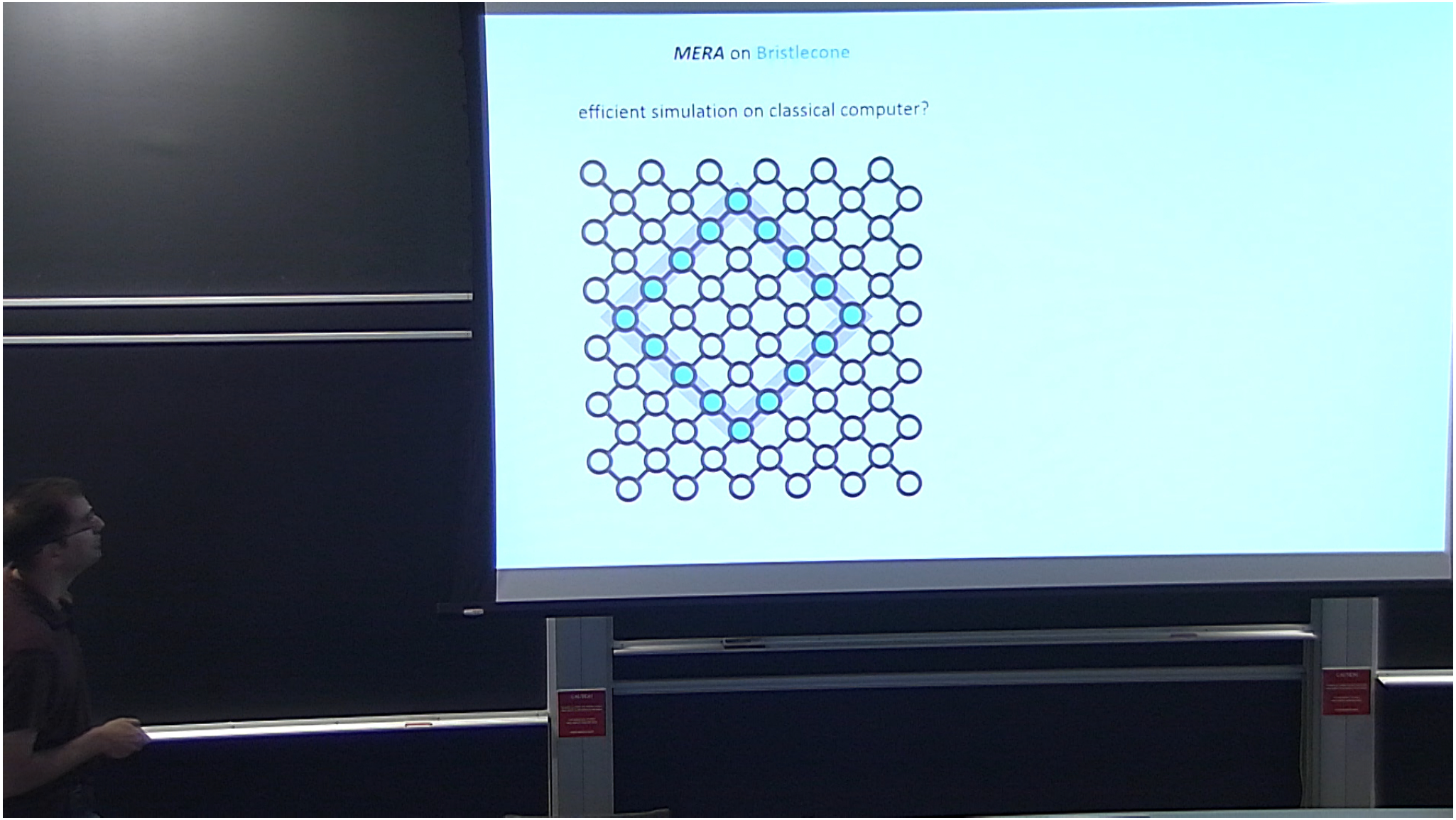


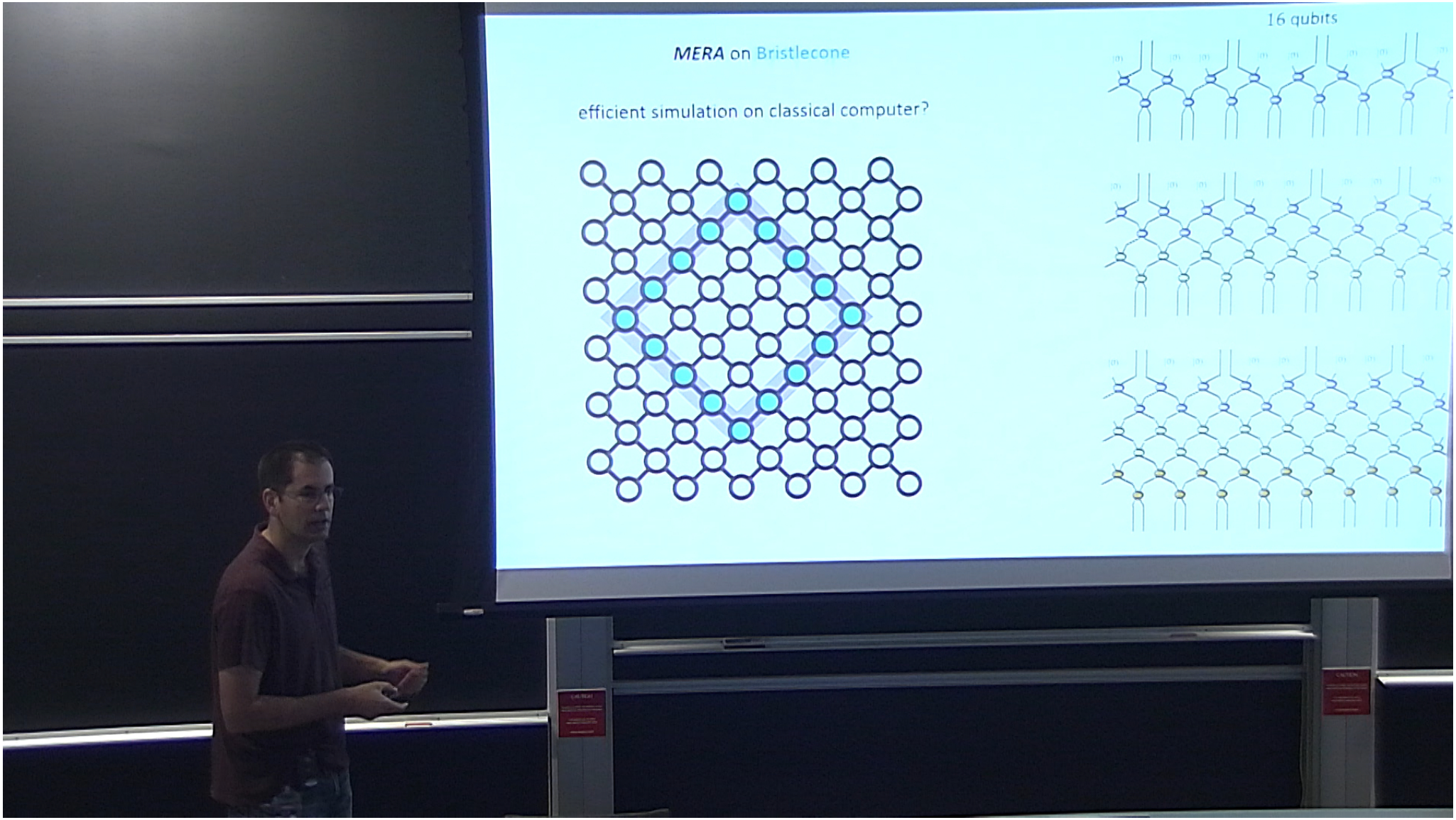
NASA

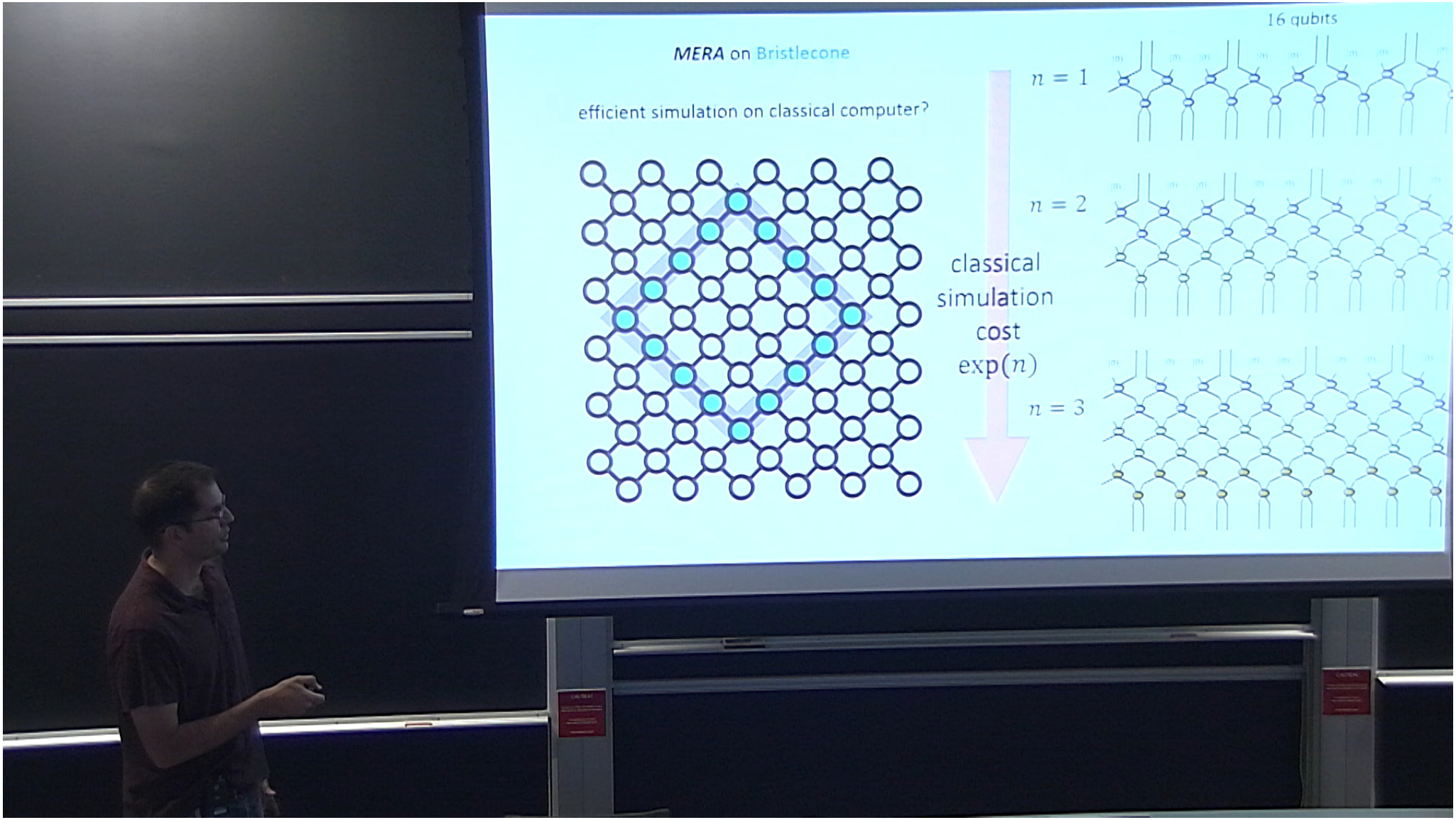


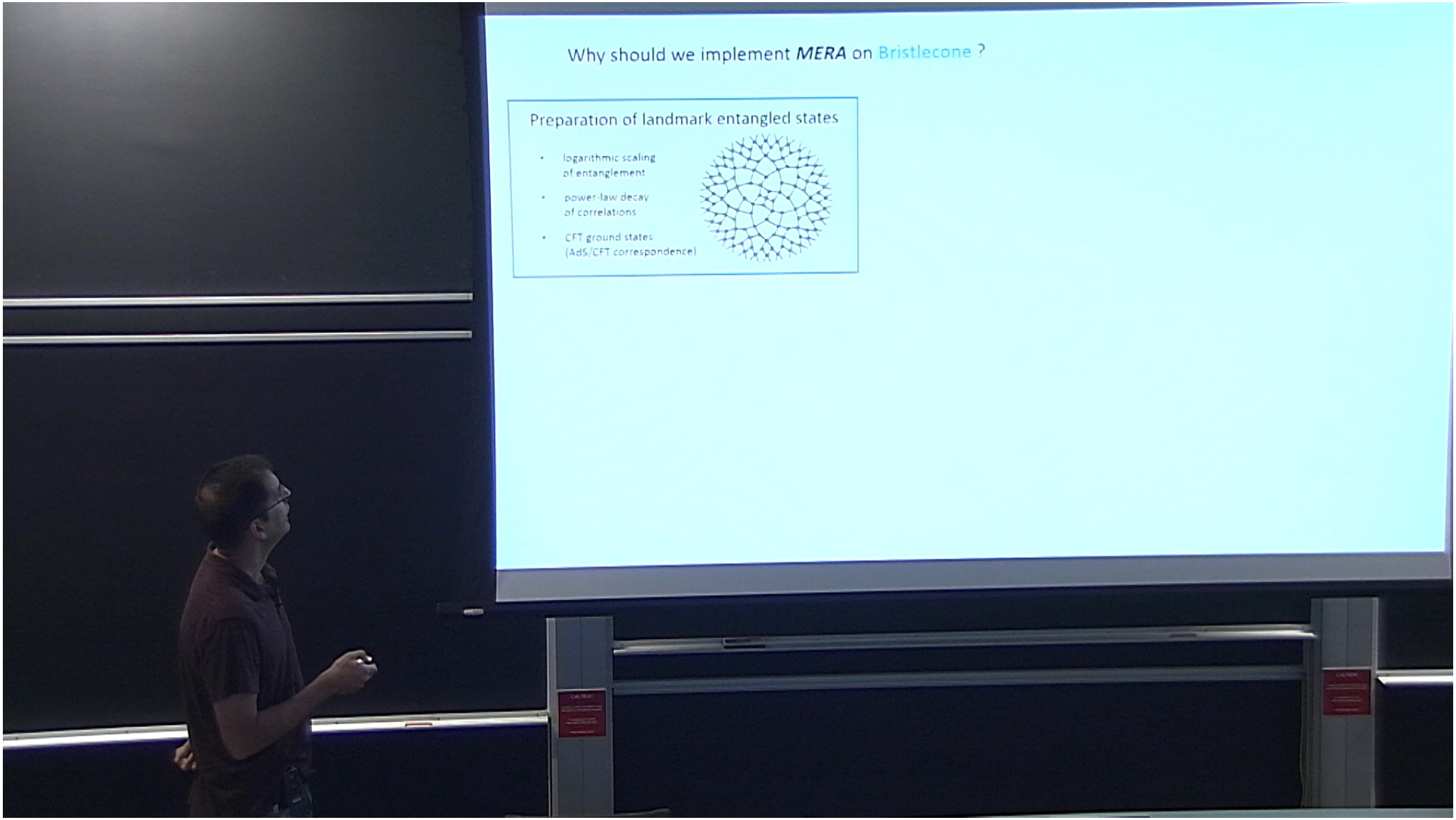

MERA on Bristlecone
Stefan Leichenauer
(X)
Dave Bacon
(Google AI)
Dvir Kafri, Yu Chen
(Google AI quantum)


MERA on Bristlecone
2 qubits
4 qubits
8 qubits
16 qubits
32 qubits


MERA on Bristlecone
efficient simulation on classical computer?


16 qubits
MERA on Bristlecone
efficient simulation on classical computer?

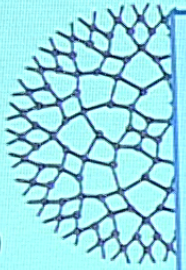

16 qubits
MERA on Bristlecone
efficient simulation on classical computer?
n = 1
n = 2
n = 3
classical simulation cost exp(n)


Why should we implement *MERA* on Bristlecone ?
Preparation of landmark entangled states
• logarithmic scaling of entanglement
• power-law decay of correlations
• CFT ground states (AdS/CFT correspondence)

Why should we implement *MERA* on Bristlecone ?

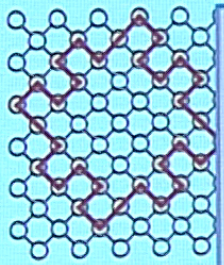
Preparation of landmark entangled states

- logarithmic scaling of entanglement
- power-law decay of correlations
- CFT ground states (AdS/CFT correspondence)



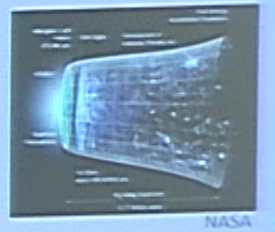
Benchmarking Bristlecone

- classical simulation available for benchmarking
- may suggest new routes to challenge quantum supremacy



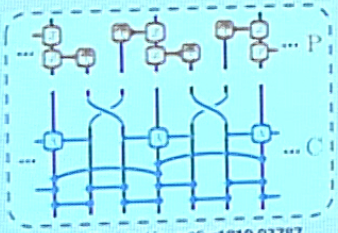
Quantum cosmology

- quantum simulation of inflation in early universe cosmology
- quantum fluctuations as seeds for large scale formation



Quantum convolutional neural network

- quantum machine learning
- identify phases of quantum matter

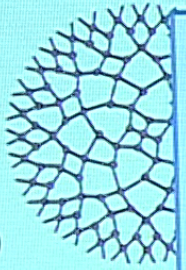


Cong, Choi, Lukin, arXiv:1810.03787

Why should we implement ***MERA*** on Bristlecone ?

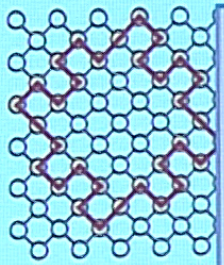
Preparation of landmark entangled states

- logarithmic scaling of entanglement
- power-law decay of correlations
- CFT ground states (AdS/CFT correspondence)



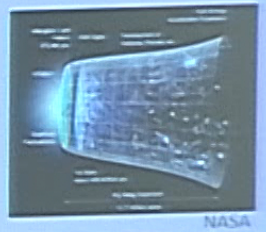
Benchmarking Bristlecone

- classical simulation available for benchmarking
- may suggest new routes to challenge quantum supremacy



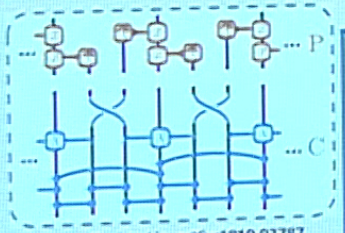
Quantum cosmology

- quantum simulation of inflation in early universe cosmology
- quantum fluctuations as seeds for large scale formation



Quantum convolutional neural network

- quantum machine learning
- identify phases of quantum matter



Cong, Choi, Lukin, arXiv:1810.03787

Hybrid classical-quantum optimization

- outperform classical simulations by quantum enhancement