# VQE on quantum magnetism

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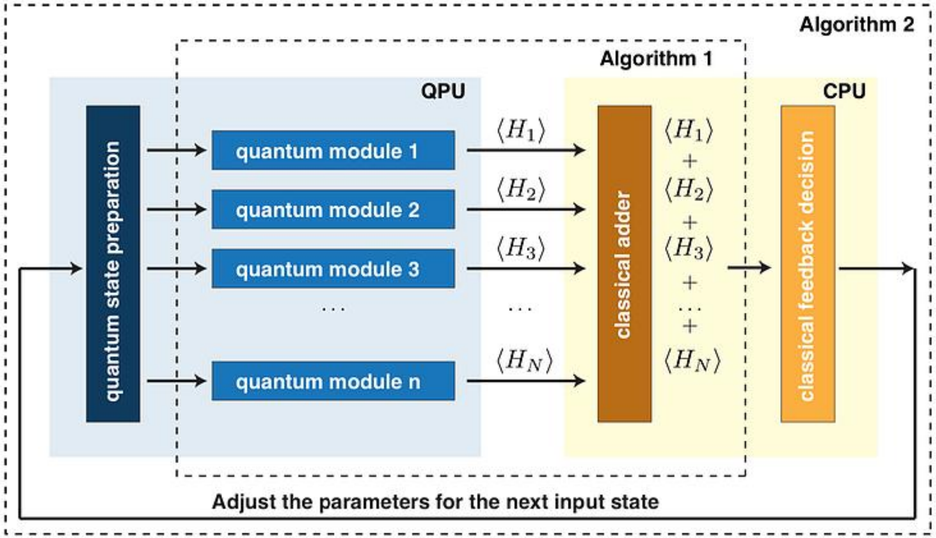
# Presentation contents




QPU $\longrightarrow$ evaluates

CPU $\longrightarrow$ optimizes

Similar to neural networks?

The algorithm follows an iterative process by evaluating some expectation value on a parameterized quantum circuit. The parameters are then to be optimized by a classical subroutine.

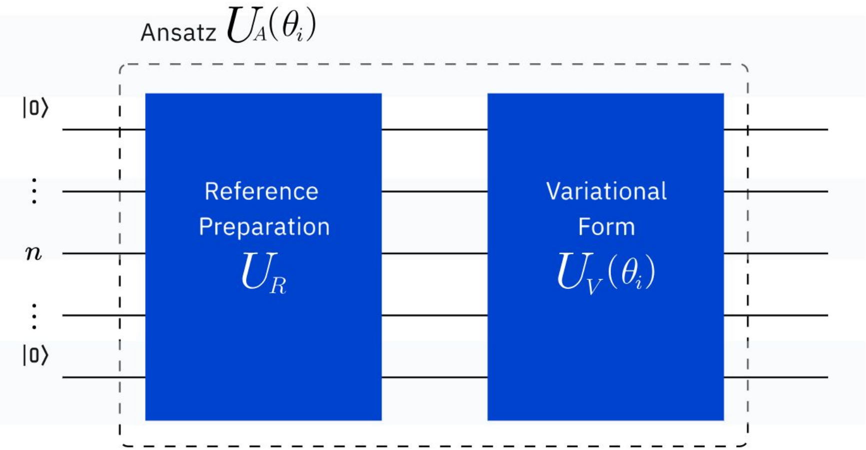
# VQE outline

$$\langle \hat{\mathrm{H}} \rangle \equiv \frac{\langle \psi | \hat{H} | \psi \rangle}{\langle \psi | \psi \rangle} \geq E_0$$

It can be proven easily that the we can’t go wrong by taking the expectation value.

Since it will be greater or equal to the exact ground energy.

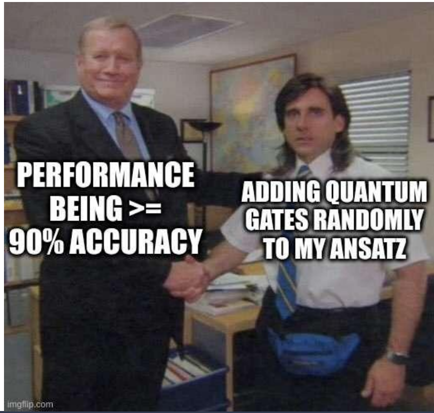
# The variational principle




Defines the optimization landscape!

It’s difficult to come up with or design one...

The variational form is the main part. The reference preparation is optional but might give a significant boost.




# The ansatz

Optimizers

Local: they focus on a singular point of the landscape
Global: opposite from local but take more resources

Gradient based: they rely on derivative evaluations in order to progres
Gradient free: distinguishes function values in different points

COBYLA: global and gradient free
QNGD: local and gradient based

# Optimization strategies

Barren plateaus: gradients vanish exponentially to the circuits complexity.

It is proven that this affects also gradient free optimizers.

Bootstrapping: utilizing previous statistical knowledge in order to head start the optimizer.

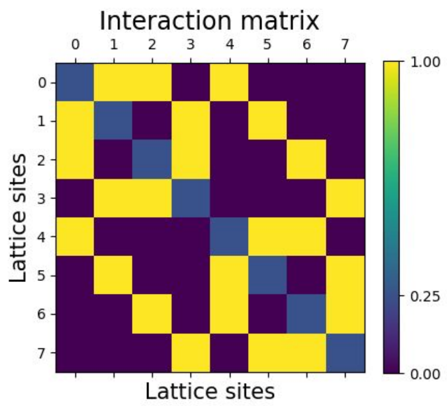
$$\mathbf{a}_{n+1} = \mathbf{a}_n - \gamma \nabla F(\mathbf{a}_n)$$

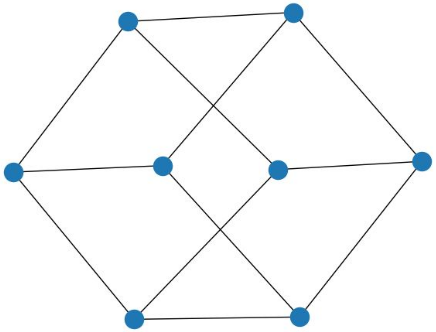
that's not QNGD

QNGD is a form of gradient that is independent of the parameterization (not to be confused with the ansatz).

Maps functions to probability distributions and computes their distance (via KL divergence).

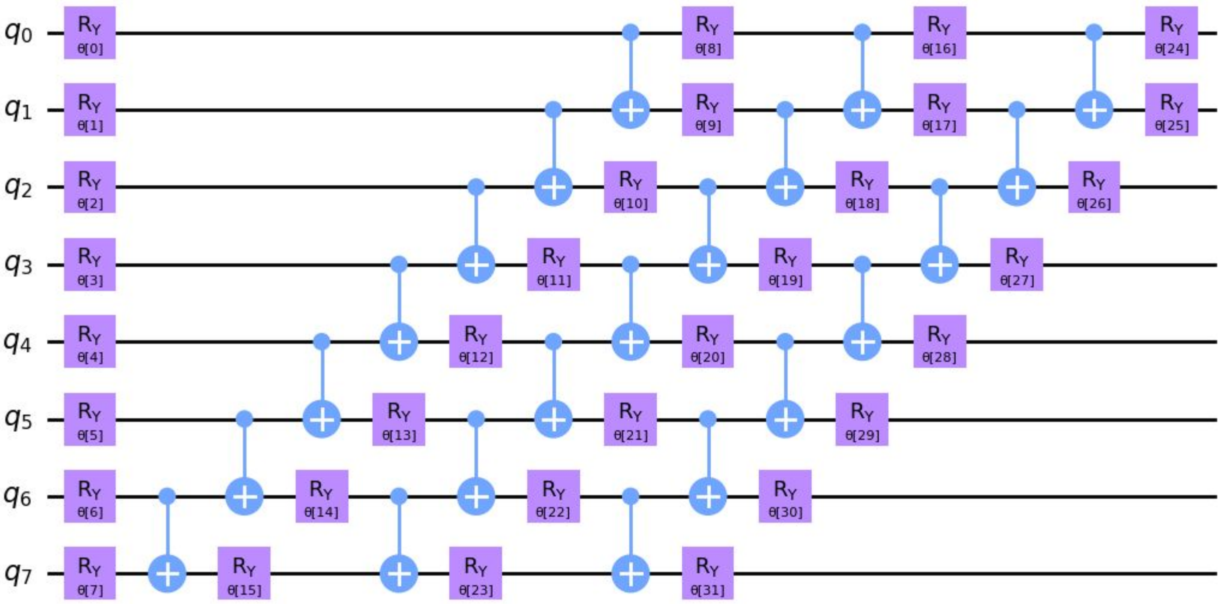
# Quantum natural gradient descent



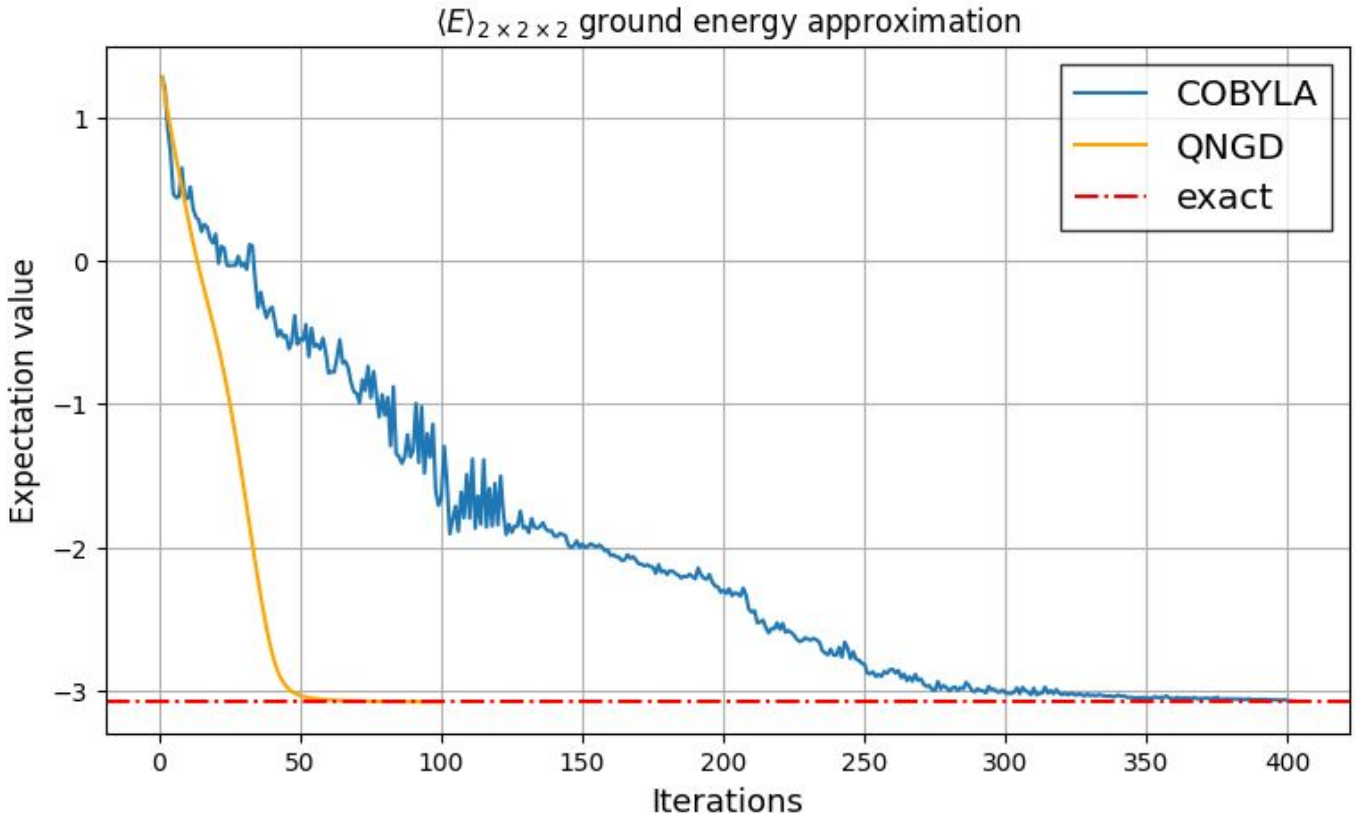
$$\hat{\mathrm{H}} = -\sum_{\langle i,j\rangle} \hat{\sigma}_i^z \hat{\sigma}_j^z - \frac{1}{4}\sum_i \hat{\sigma}_i^x .$$

VQE applied on a cube

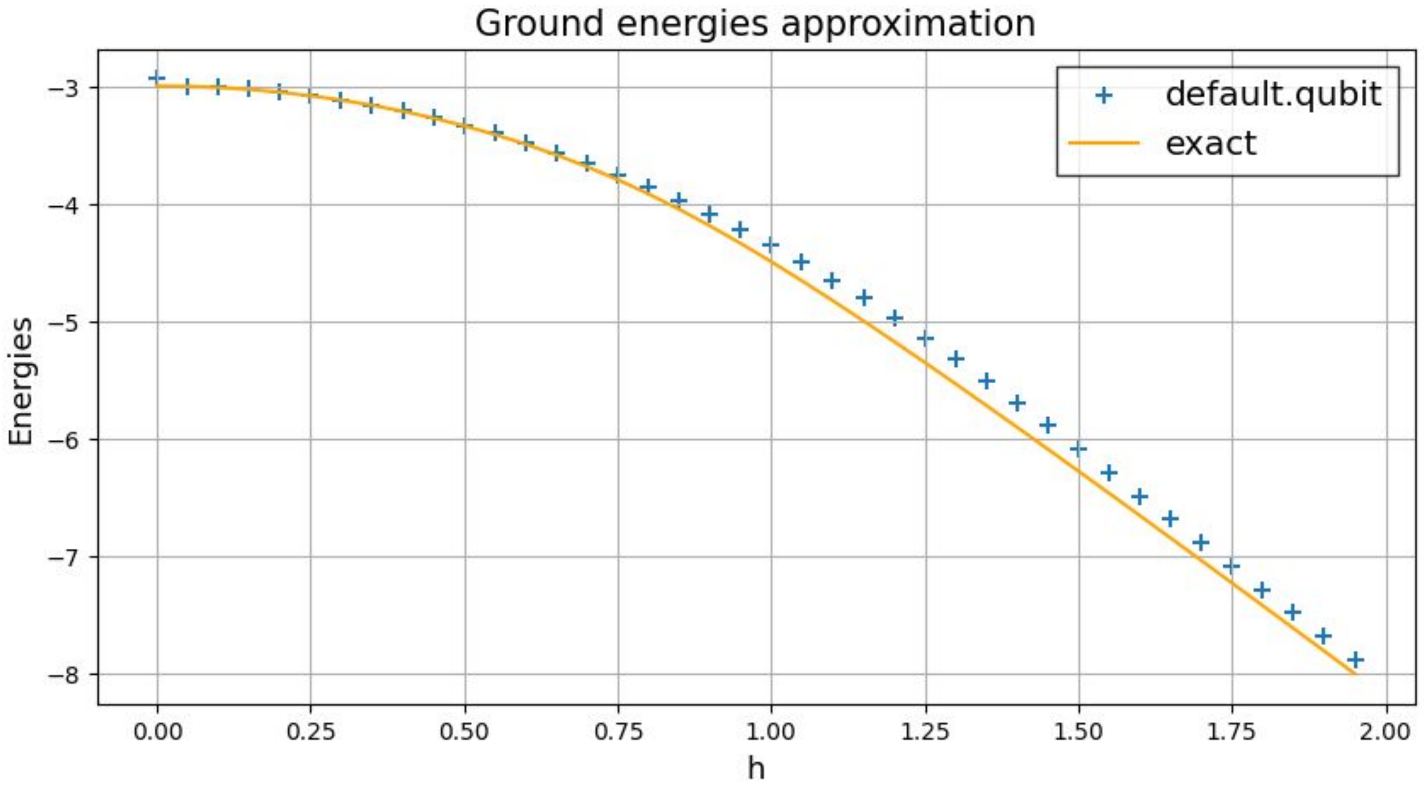



The ansatz preserves only real amplitudes while the reverse linear entanglement is equivalent to full.

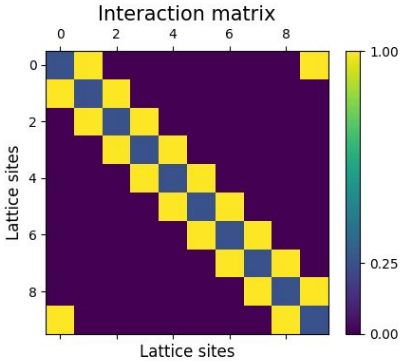
# VQE applied on a cube

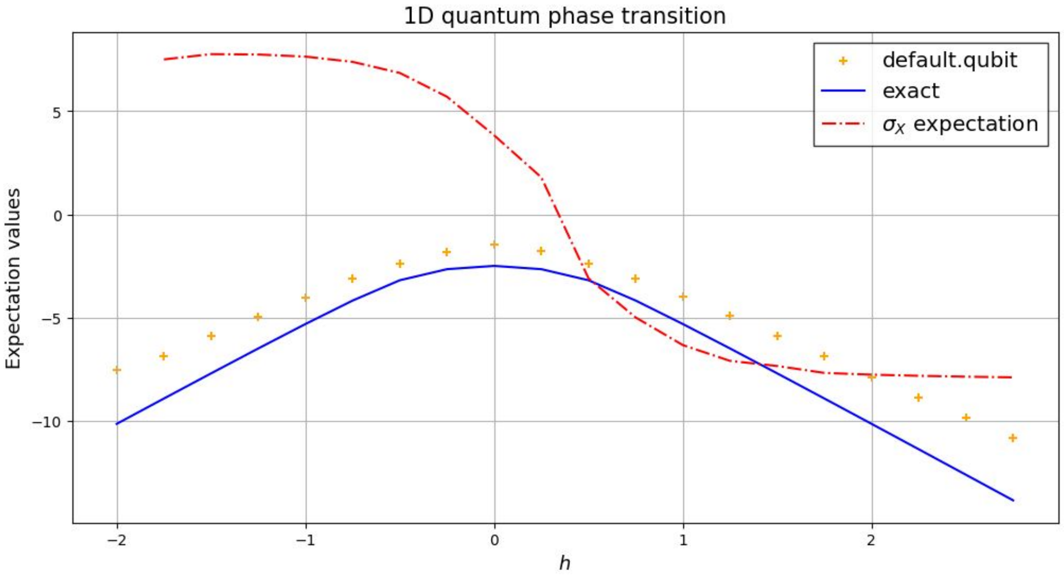


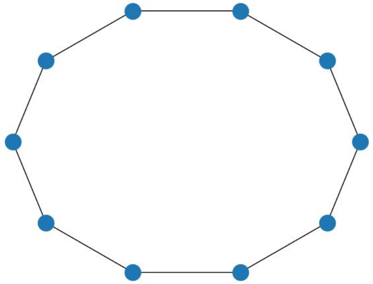

VQE applied on a cube




VQE applied on a cube

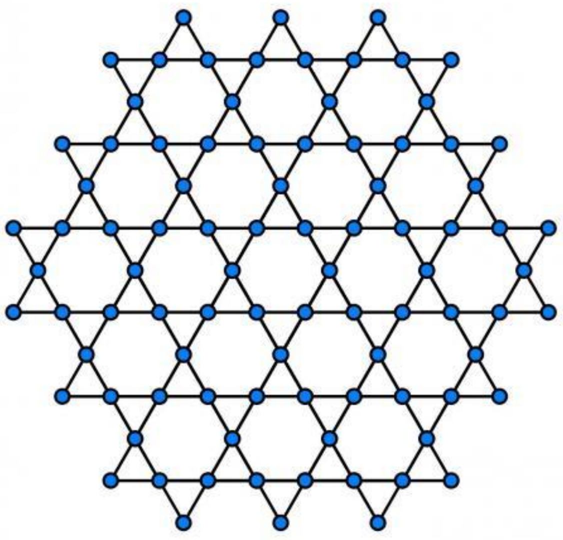


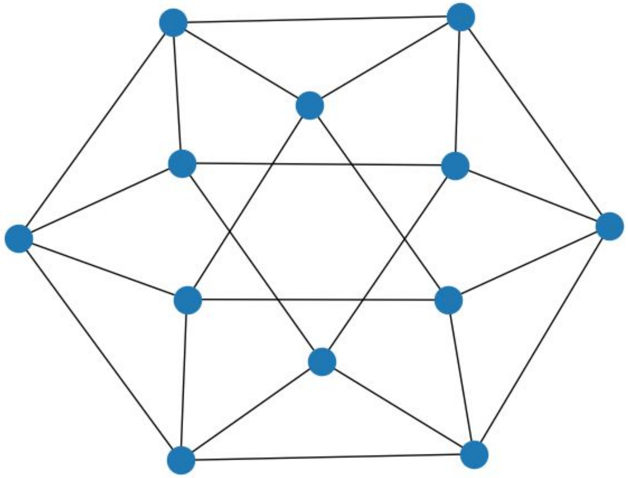



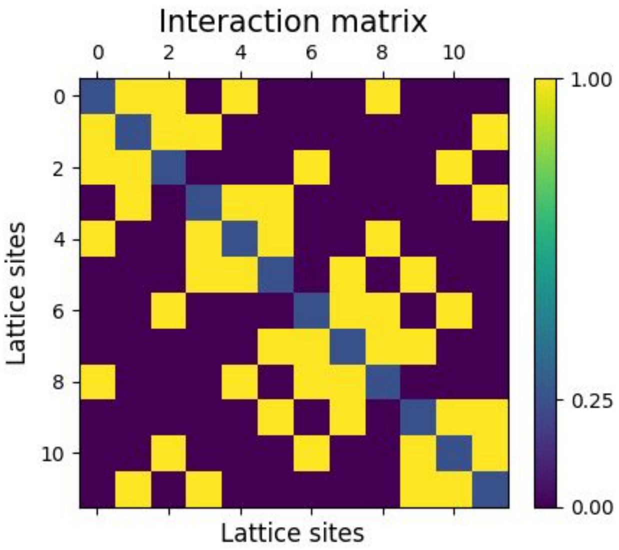



# 1D quantum phase transition

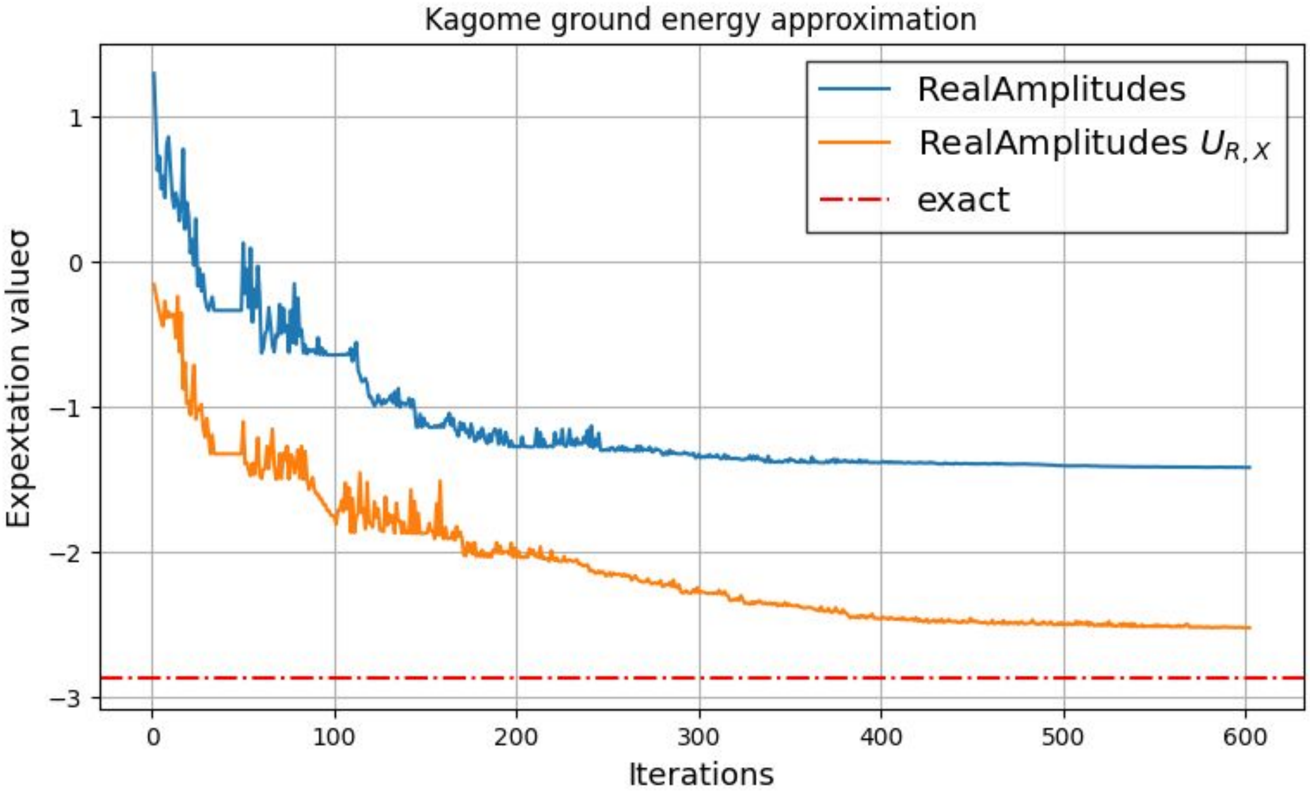
The Kagome’s lattice intriguing geometric is includes triangles arranged in a hexagonal pattern.








# VQE for a Kagome lattice




VQE for a Kagome lattice

# Questions?

Contact: pkonstantinidis2@tuc.gr

Ever thought of Ising sounds?

https://www.youtube.com/watch?v=mD-0VpNSJA0

References


- https://arxiv.org/abs/1304.3061