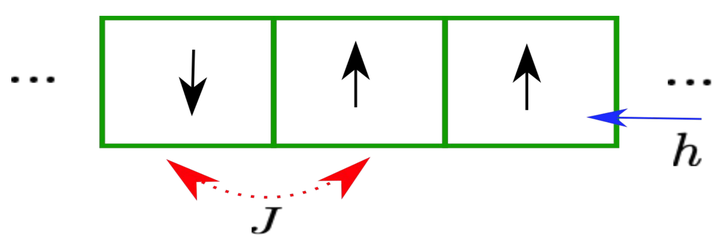
Solution for the ground state 1D transverse field Ising model using VQE

https://youtu.be/hm0VbDSW77g

N. Parra Avila , C. Garavito Cardenas
Quantum computer progamming,
Universidad Nacional de Colombia, Bogotá

Physical system

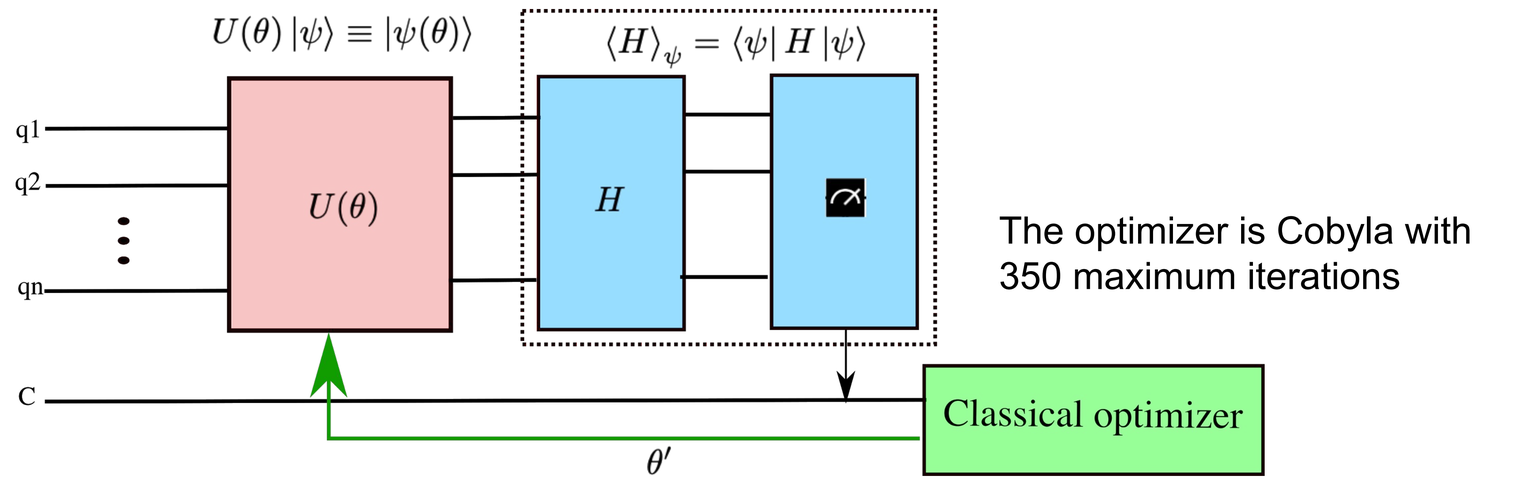
1D Ising with a trasversa field: A one-dimensional spin chain that be coupling



$$H = -J\sum_{i}^{N-1}\sigma_i^z\sigma_{i+1}^z - h\sum_{j}^{n}\sigma_j^x$$

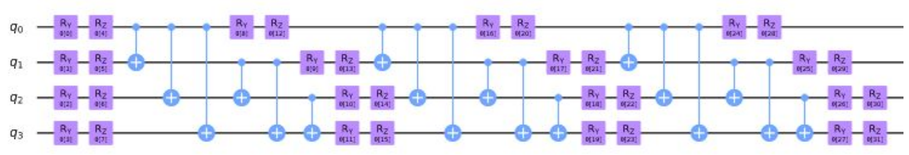
Coupling Field

VQE

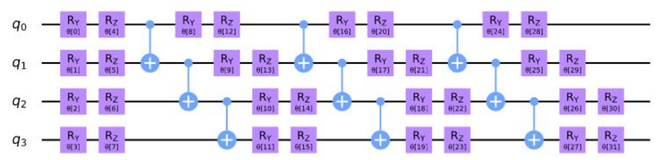


The optimizer is Cobyla with 350 maximum iterations

Variational form EfficientSU2



Full entanglement

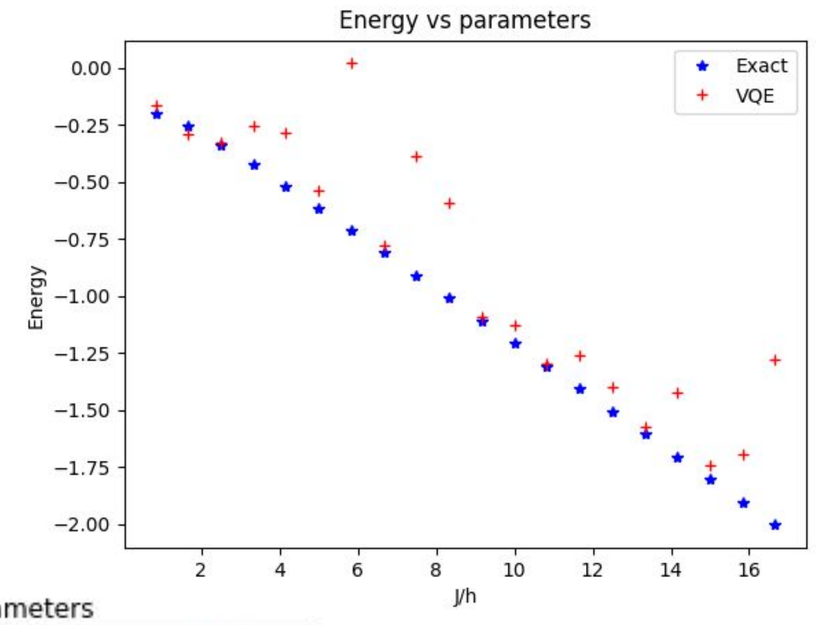


Linear entanglement

Results

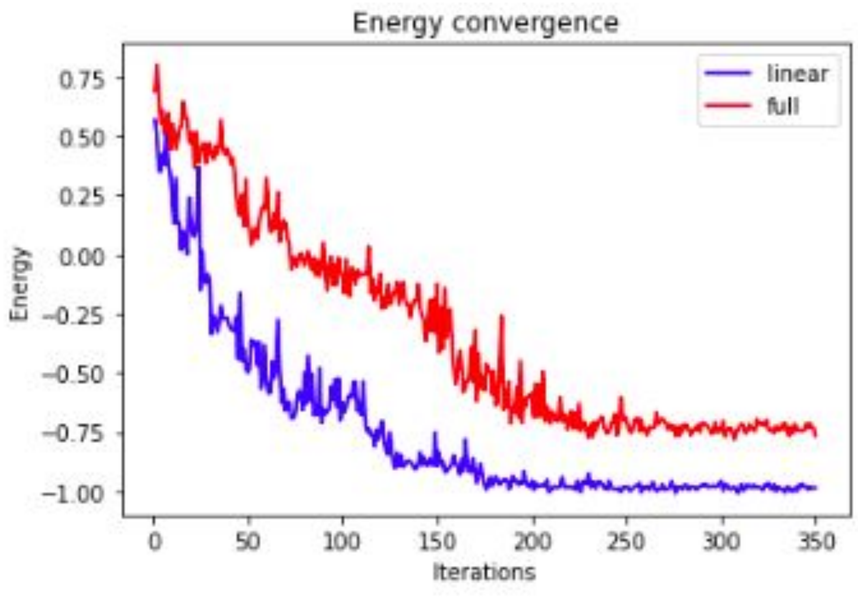
Qiskit + QuTiP Quantum Toolbox in Python

Spin chain with N = 3

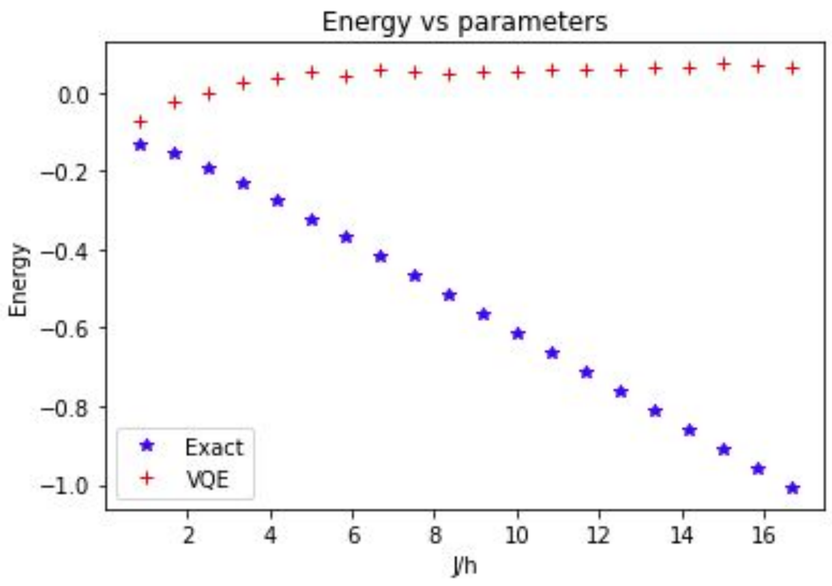


Good results in some parameter regimes but problems in others
6 Qubits

Spin chain with N = 3



Exact energy found: -1.0098
VQE energy with linear: -0.8821
VQE energy with full: -0.7833
Porcentual error with linear: 12.65 %
Porcentual error with full: 22.43%



Spin chain with N = 2

Important limitation in a simple case !! why?
2 Qubits

Parameters J=0.5 and h=0.06

Conclusions

We successfully implement a VQE to find the ground state for the Tranversal-field 1D Ising with three spins. We demonstrate that the VQE algorithm highly depends of the variational form. Particularly, we show that in spite that the solutions using both linear and full entanglement variational forms converges, the VQE performs the better with the linear variational form, getting an error of 12.64% compared with the exact solution. Also, we show that for some parameters of the Hamiltonian, ***J/h***, the VQE is not able to compute an accurate value for the ground energy.

Acknowledgements

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References

[1] IBM Research.Qiskit Texbook-VQE, 2020 (accessedDecember 13, 2020).
[2] John Preskill. Quantum computing in the nisq era and beyond. Quantum, 2:79, Aug 2018.