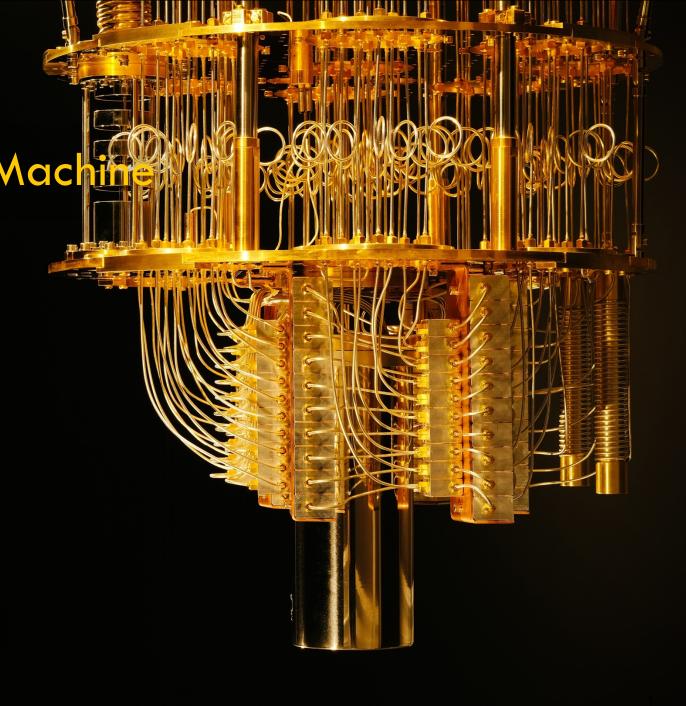
Quantum Computation for Machin

Learning, AI,

and Optimization

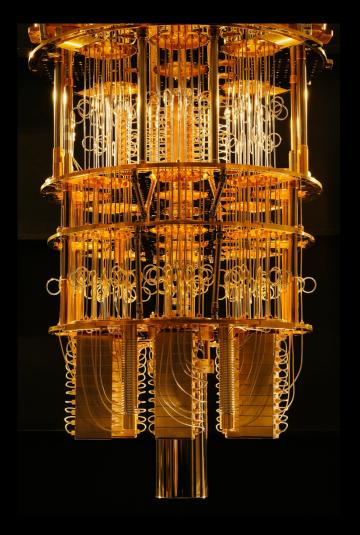
Zlatko K. Minev, Ph.D.

IBM Quantum @ TJ Watson



Experimental Superconducting Quantum Computing

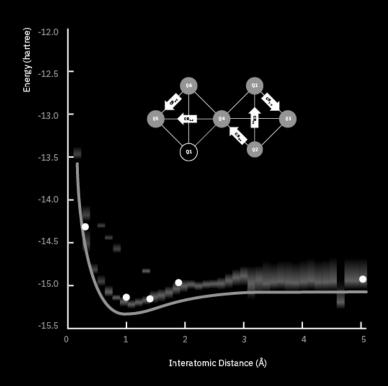
Hardware



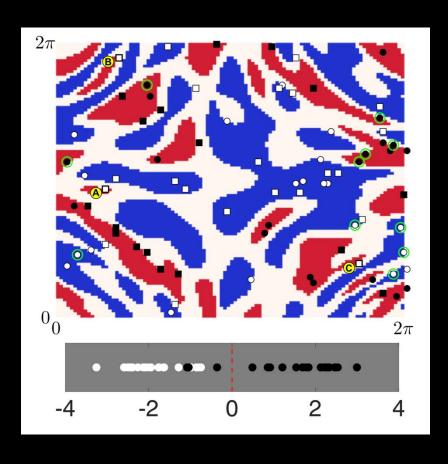
Chemistry



Beryllium hydride (BeH₂):



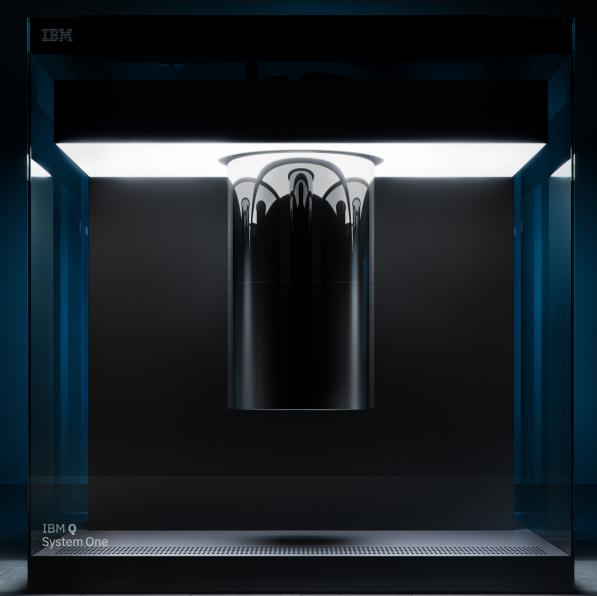
Machine Learning

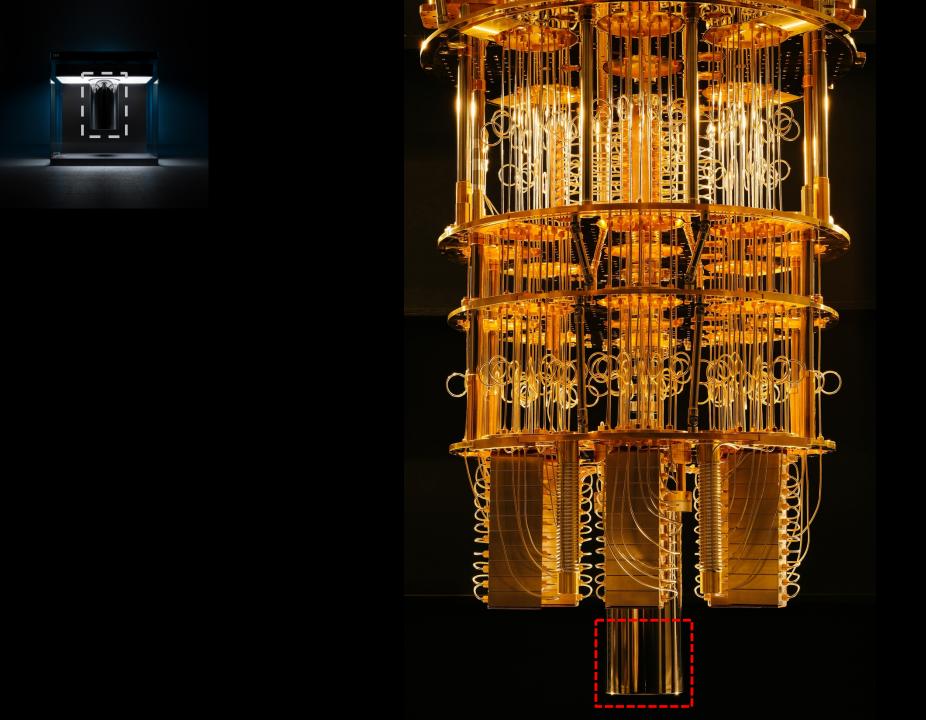


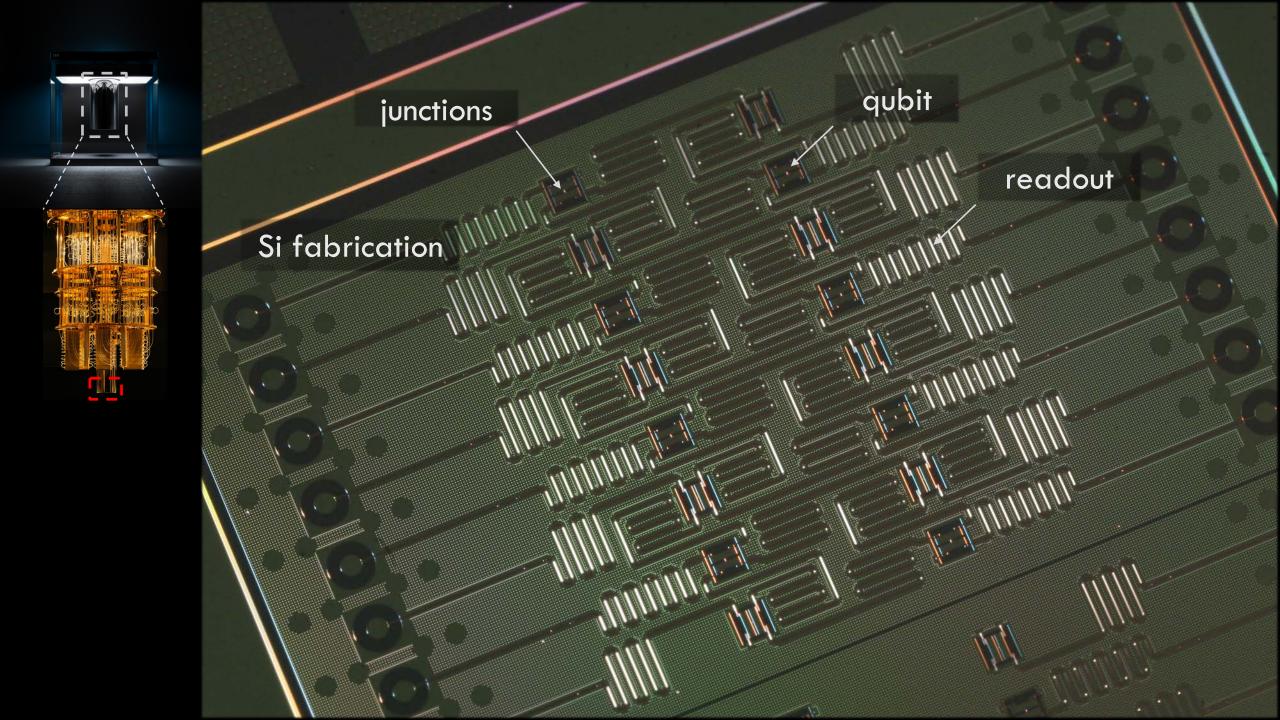
Cloud-based quantum computing

What does today's hardware look like?

Commercial cloud service

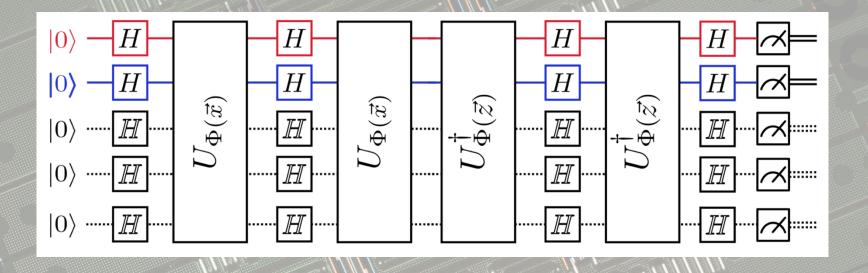








From chip to algorithm



Quantum Applications

Possible application areas for quantum computing

We believe the following areas might be useful to explore for the early applications of quantum computing:

Chemistry

Material design, oil and gas, drug discovery

Artificial Intelligence

Classification, machine learning, linear algebra

Optimization

Portfolio optimization, scenario analysis, pricing



Letter article for Nature doi:10.1038/nature23879 Hardware efficient variational quantum magnets Hardware efficient sand quantum magnets The small molecules and quantu Hardwal molecules and quantum magnets. Hardwal molecules and quantum phase estimation algorithm. Abhinav Kandalat*, Antonio Mezzacapot*, Kristan Temme¹, Maika Takita¹, Markus Brink¹, Jerry M. Chow¹ & Jay M. Gambettal Abhinav Kandalat*, Antonio Mezzacapot*, Kristan Temme², Maika Jagorithm can produce extremation. Figure 1 | Quantum chemistry on a superconducting quantum con a quantum chemistry on a superconducting quantum con a quantum con Figure 1 | Quantum chemistry on a superconducting quantum conprocessor. Solving electronic structure problems on a quantum conprocessor. Solving electronic structure and qubit operators. a particular processor mappings between fermionic and qubit operators. Processor. Solving electronic structure problems on a quantum con a problem of a quantum con a guantum con a quantum con a quant relies on mappings between fermionic and qubit operators. a., Par relies on mappings between fermionic and qubit operators. a., Par mapping of eight spin orbitals (drawn in blue and red, not to scal mapping of eight spin orbitals (drawn in blue and red, not to scal mapping of eight spin orbitals (drawn in blue and red, not to scal eight aubits. which are then reduced to six aubits orbitals. Problem using the quantum phase estimation algorithm 15. Although accurate energy estimates for this algorithm can produce extremely accurate energy estimates for this algorithm can produce applies stringent requirements. mapping of eight spin orbitals (drawn in blue and red, not to see the mapping of eight spin orbitals (drawn in blue and red, not to see the mapping of eight qubits, which are then reduced to six qubits owing to see the length of the bare instruction of the bare instruct Problem using the quantum phase estimation algorithm¹⁵. Although extremely accurate energy estimates for this algorithm can produce extremely stringent requirements on the this algorithm chemistry arms hardware. eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits, which are then reduced to six qubits owing to fem eight qubits. Problem using can produce extremely accurate energy estimates for this algorithm can produce extremely accurate energy estimates for this algorithm chemistry. At applies stringent requirements on the quantum chemistry and the quantum chemistry are quantum chemistry and the quantum chemistry accurate energy estimates for the quantum chemistry.

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Because the qubits are all initialized set of Z rotations of $\mathcal{L}_{q,0}(\theta)$ is not in

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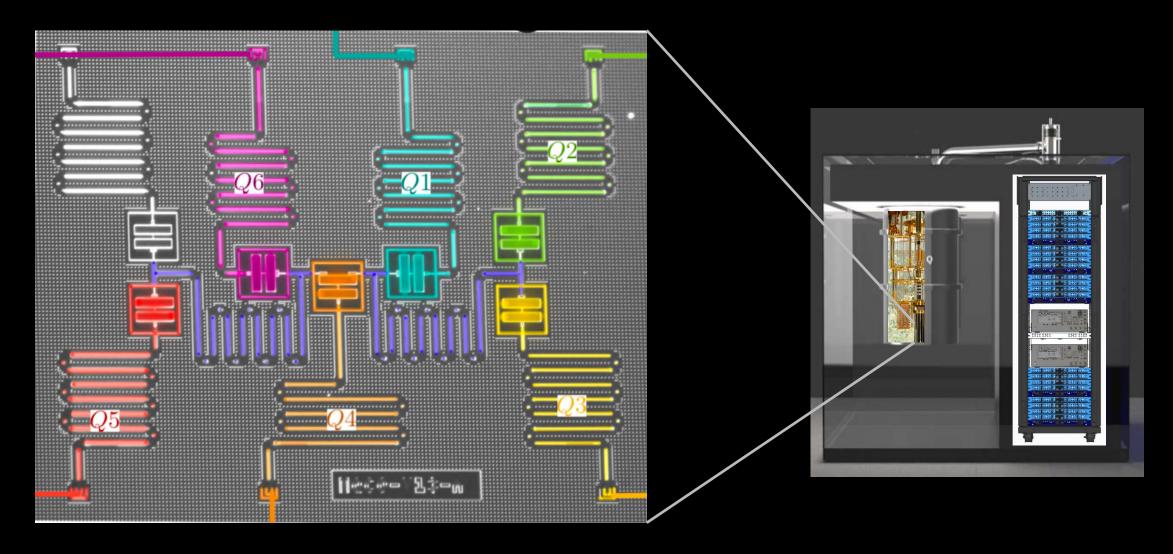
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Experimental Results

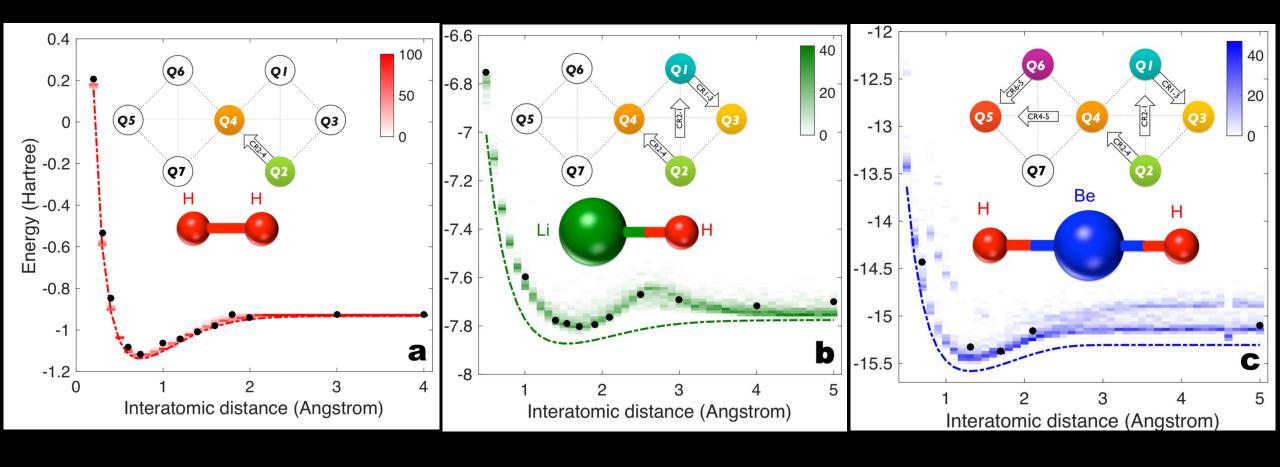
Computing the ground state energy for small molecules





Experimental Results

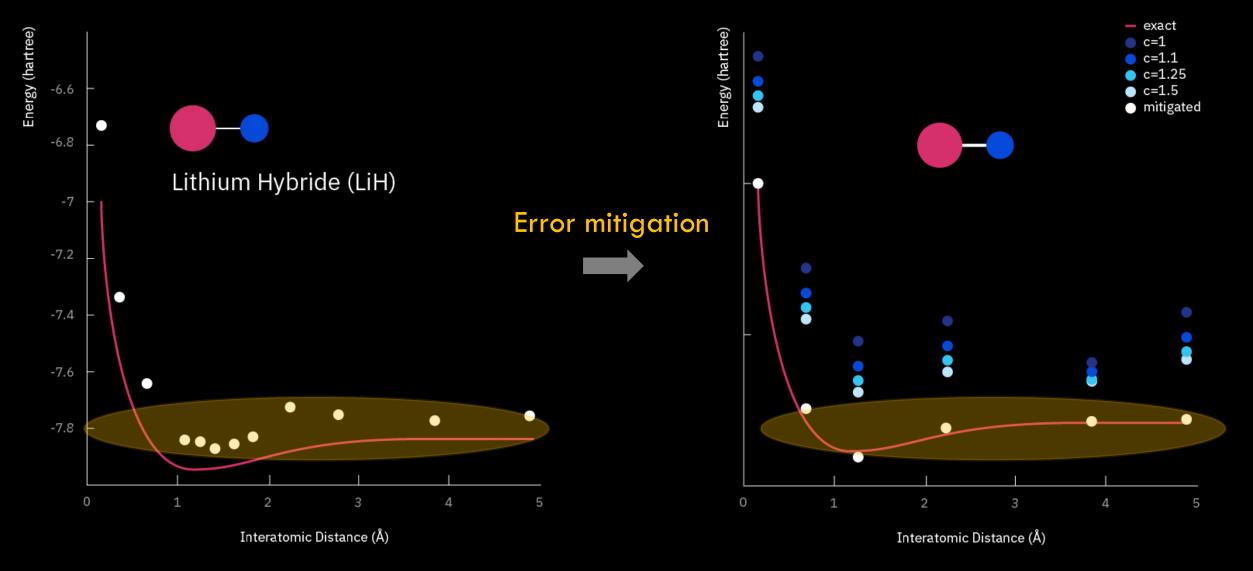
Computing the ground state energy for small molecules





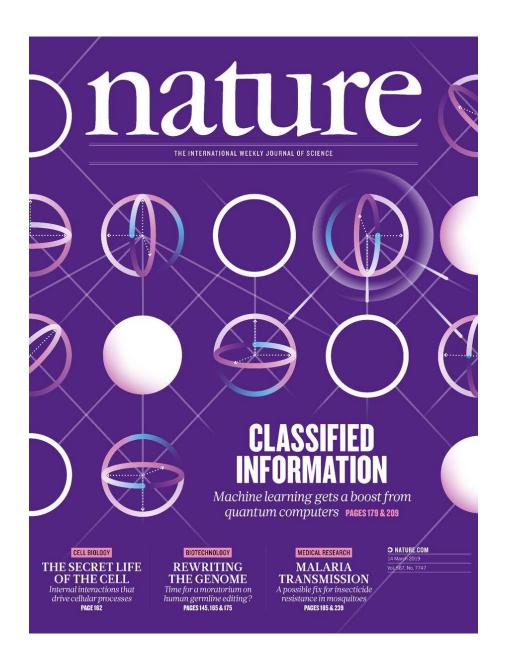
Error mitigation: improving accuracy

Recovering correct result in the presence of noise



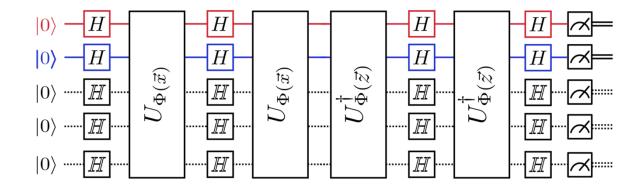
Quantum Machine Learning

Example: Support Vector Machines (SVM)



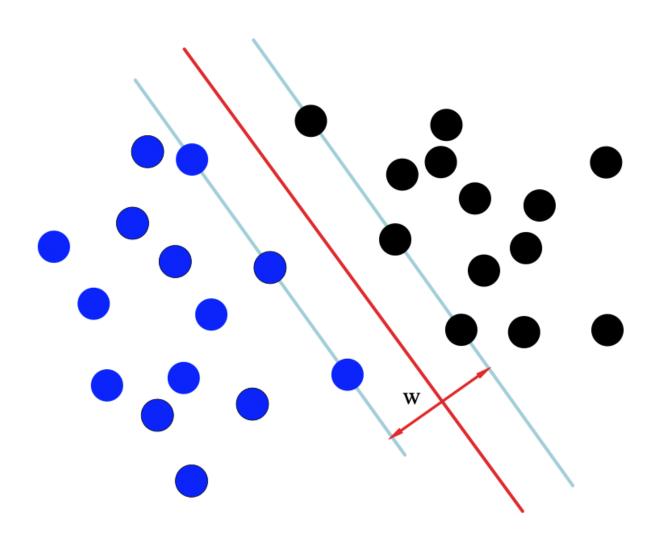
Classical vector \vec{x} is encoded into the exponentially-large quantum state space.

Quantum short depth circuits as classifiers



IBM *Nature* **567**, 209 (2019)

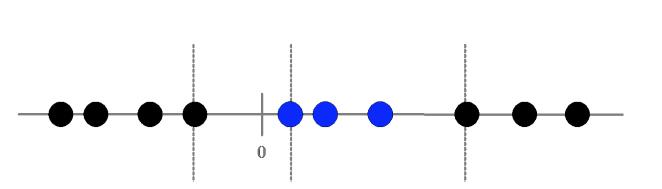
Classical Computing: SVM Classification

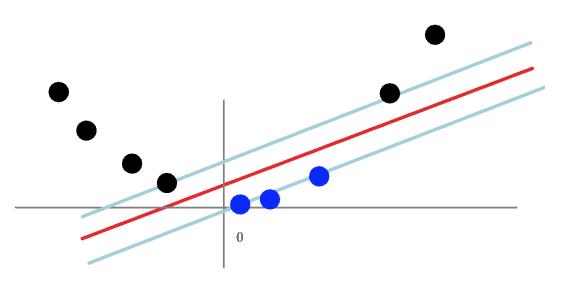


Classical Computing: Feature Space

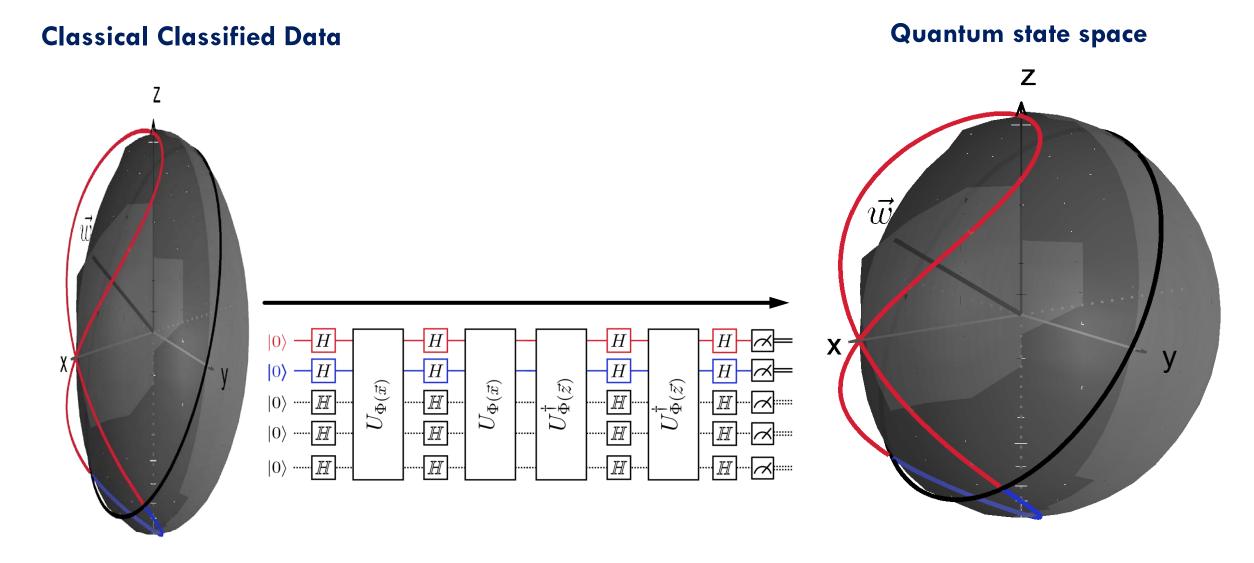
Data that is *not* linearly separable may become linearly separable by increasing dimensionality.

Non-linear classification at cost of dimensionality



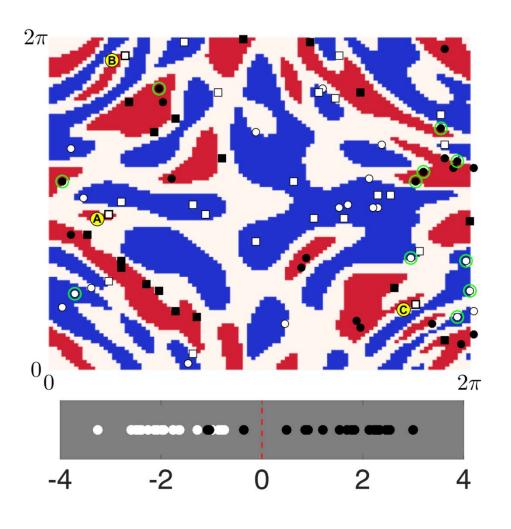


Quantum-Enhanced Feature Space

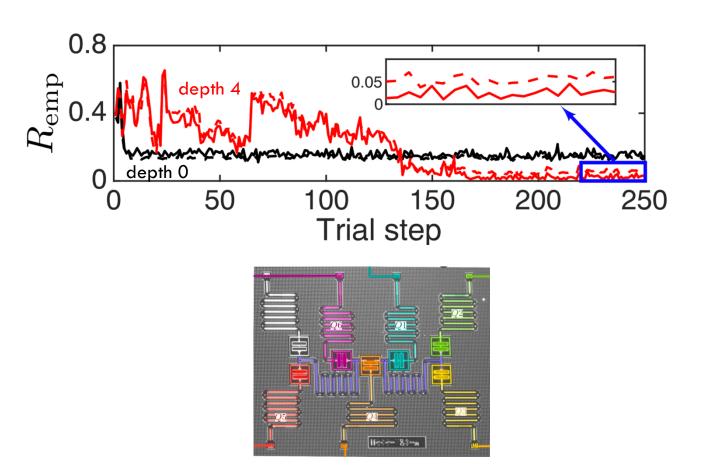


Quantum-Enhanced Feature Space

Classical Classified Data



Training classifier in quantum state space

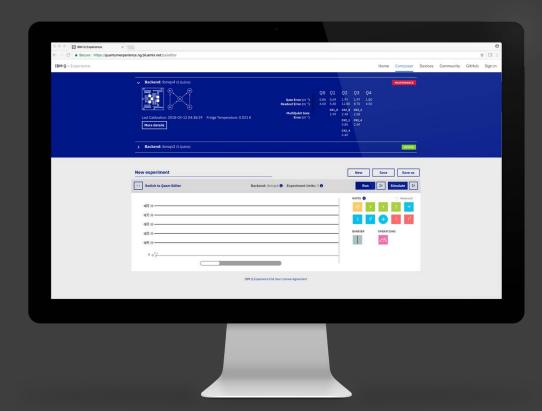


How to start using quantum computers?

Qiskit

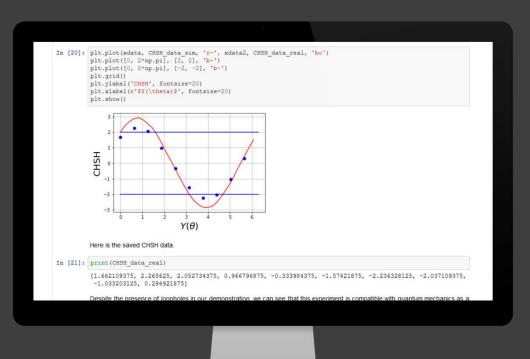
Quantum Community

IBM Q Experience



- Open to public for research and education
- Access via IBM Cloud

QISKit.org



Software kit for short depth quantum circuits and building near term applications and experiments on quantum computers.

Quantum Computing

IBM Technical Presentation

Thank you!

Zlatko K. Minev, Ph.D.

