CONICET

UNIVERSIDAD NACIONAL de MAR DEL PLATA

I C Y T E

INSTITUTO DE INVESTIGACIONES CIENTÍFICAS Y TECNOLÓGICAS EN ELECTRÓNICA

The Abdus Salam International Centre for Theoretical Physics

# FPGA uses for Reinforcement Learning and Quantum Computing

Agustin Silva

# Outline

- Reinforcement Learning
  - FPGA for RL (Acceleration)
- Quantum Computing
  - FPGA for QC (Building)
- Reinforcement Learning in QC
  - FPGA for RL in QC (Real-time control)
- Quantum Computing in RL
  - FPGA for QC in RL (Simulation)

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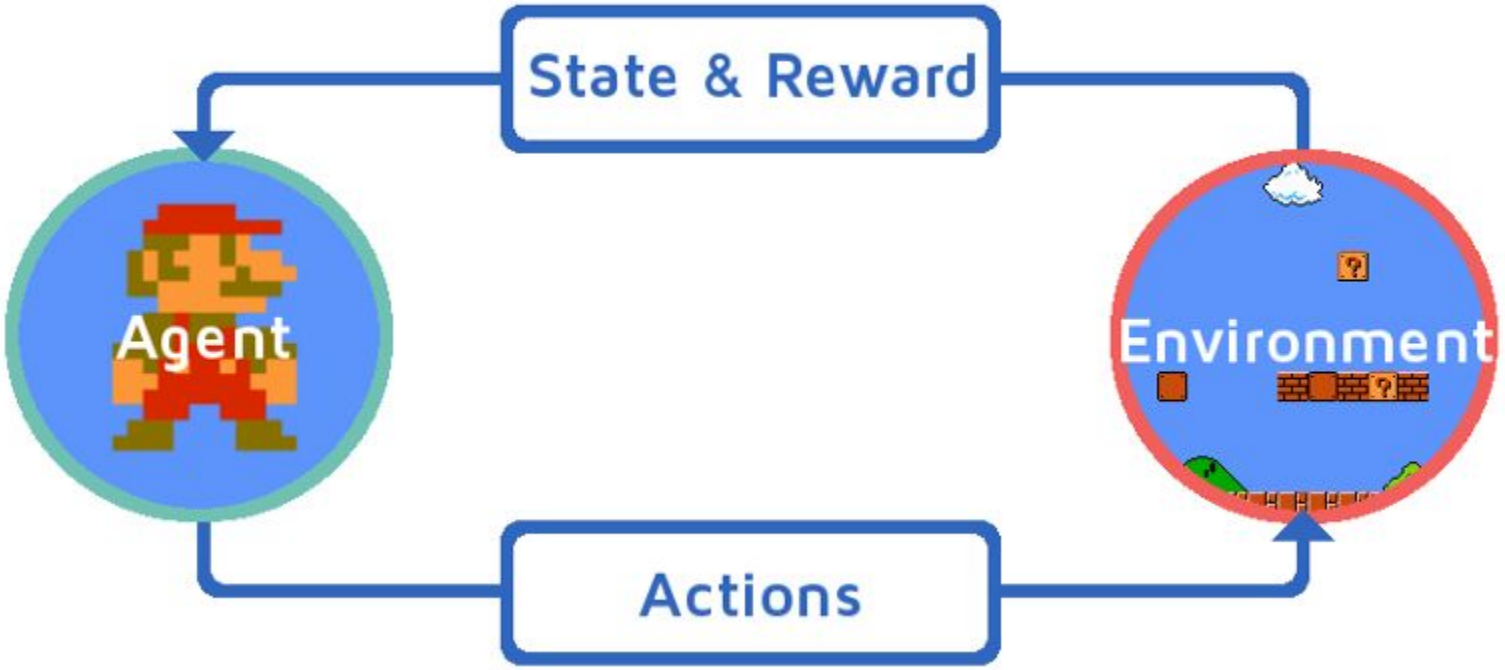
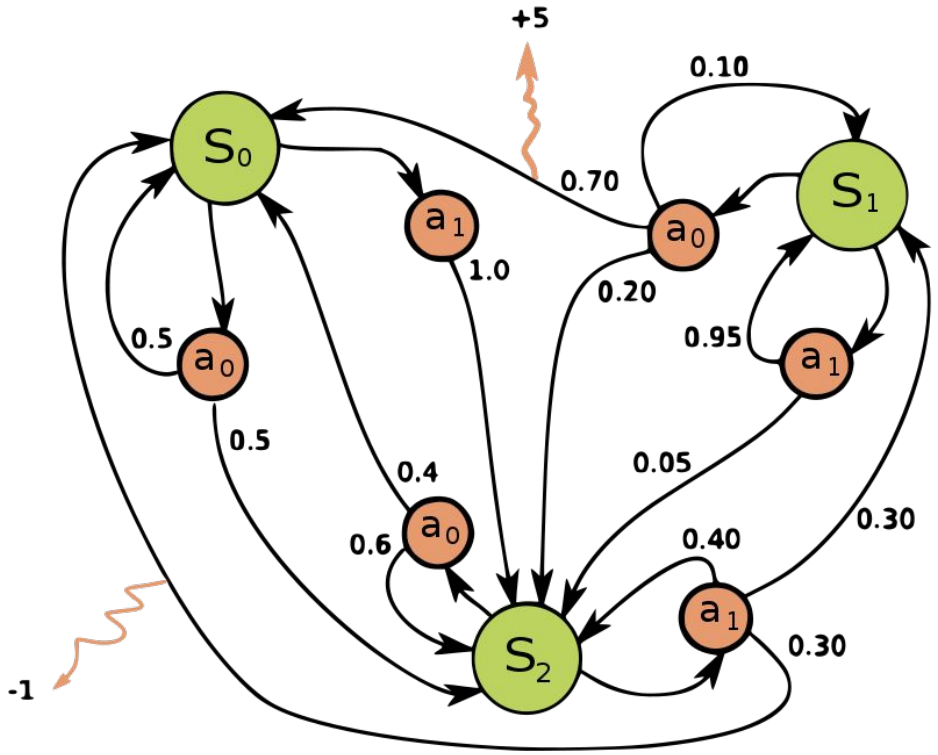
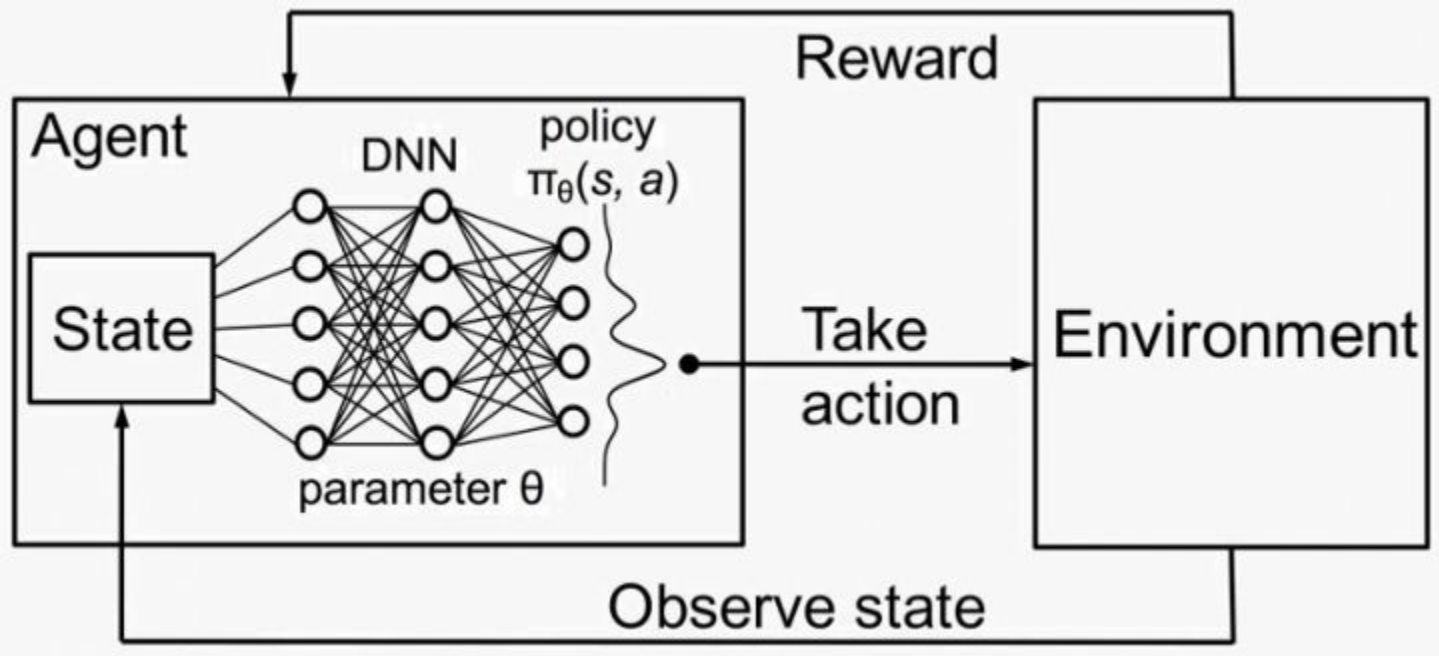
# Reinforcement Learning



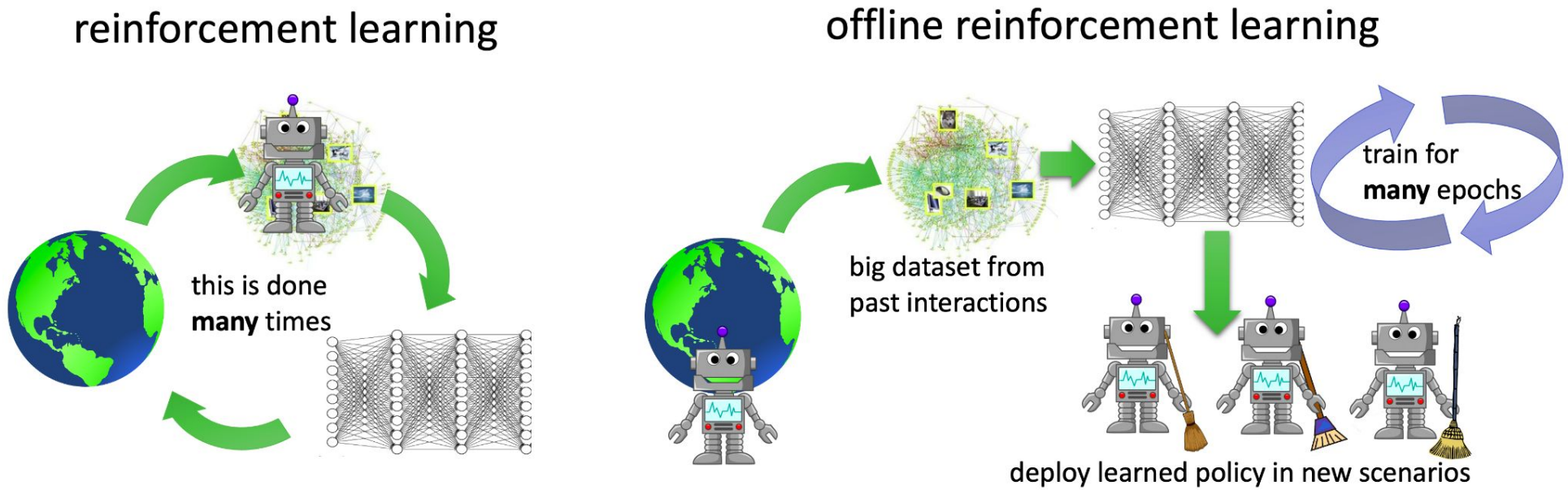
# Markov Decision Process



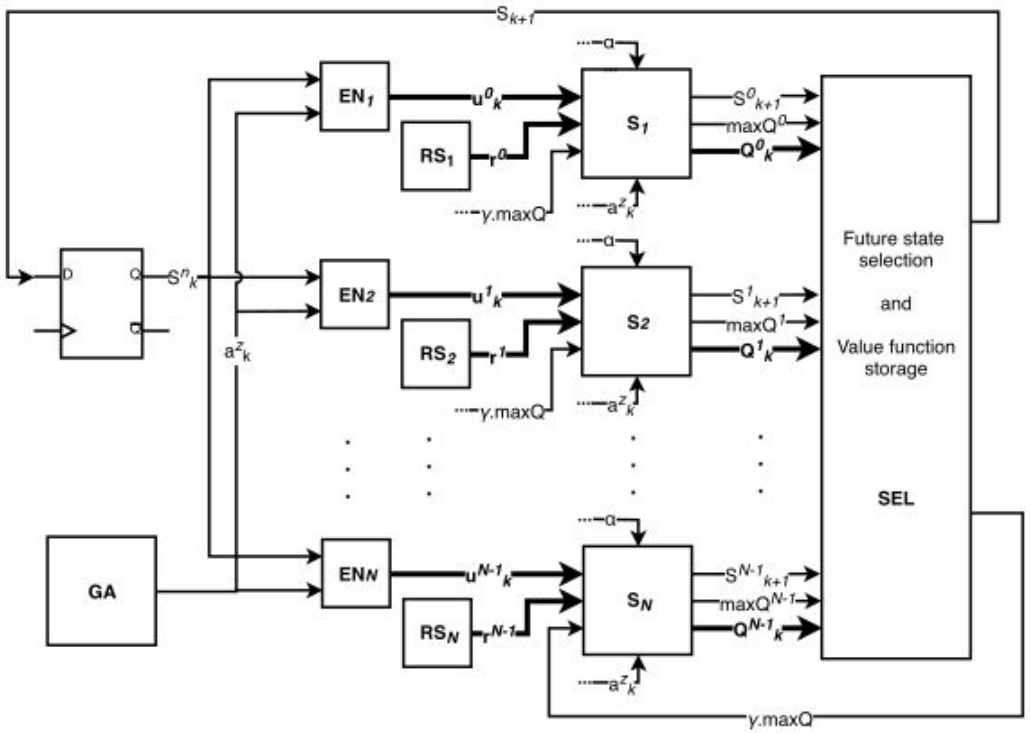
# Deep Reinforcement Learning



# Online vs Offline Reinforcement Learning



# FPGA for Reinforcement Learning (Acceleration)




[2018 - Parallel Implementation of Reinforcement Learning Q-Learning Technique for FPGA]

# FPGA for Reinforcement Learning (Acceleration)

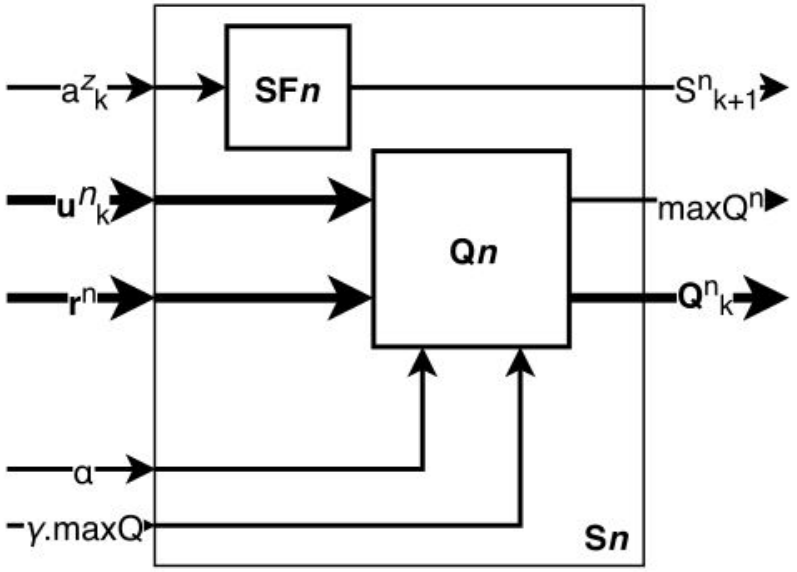
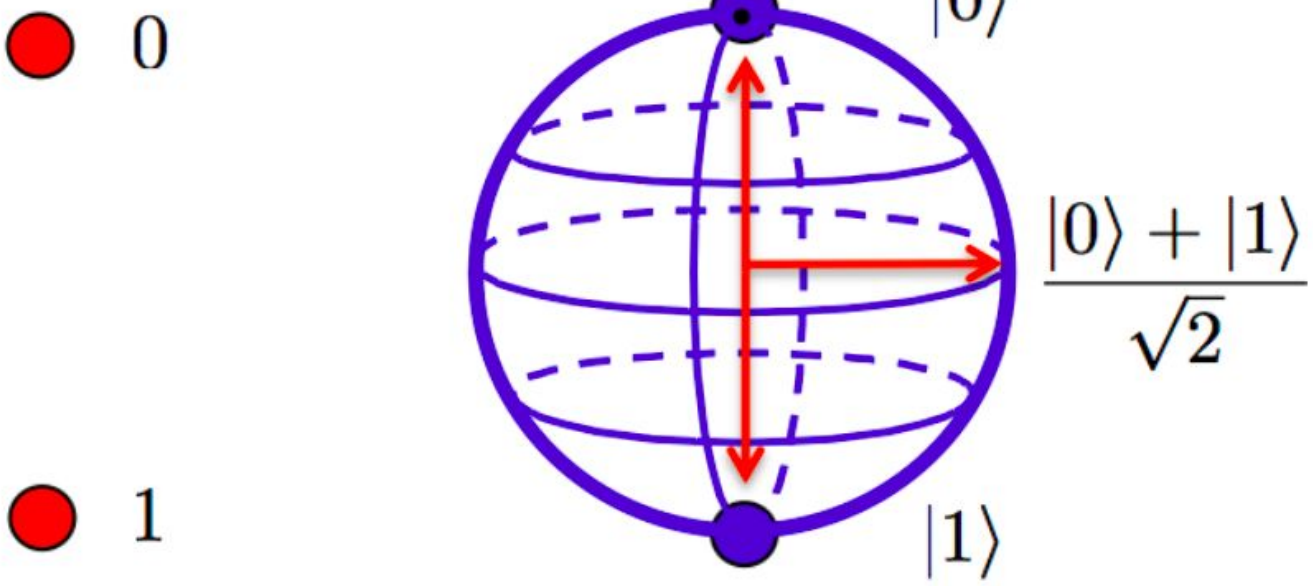


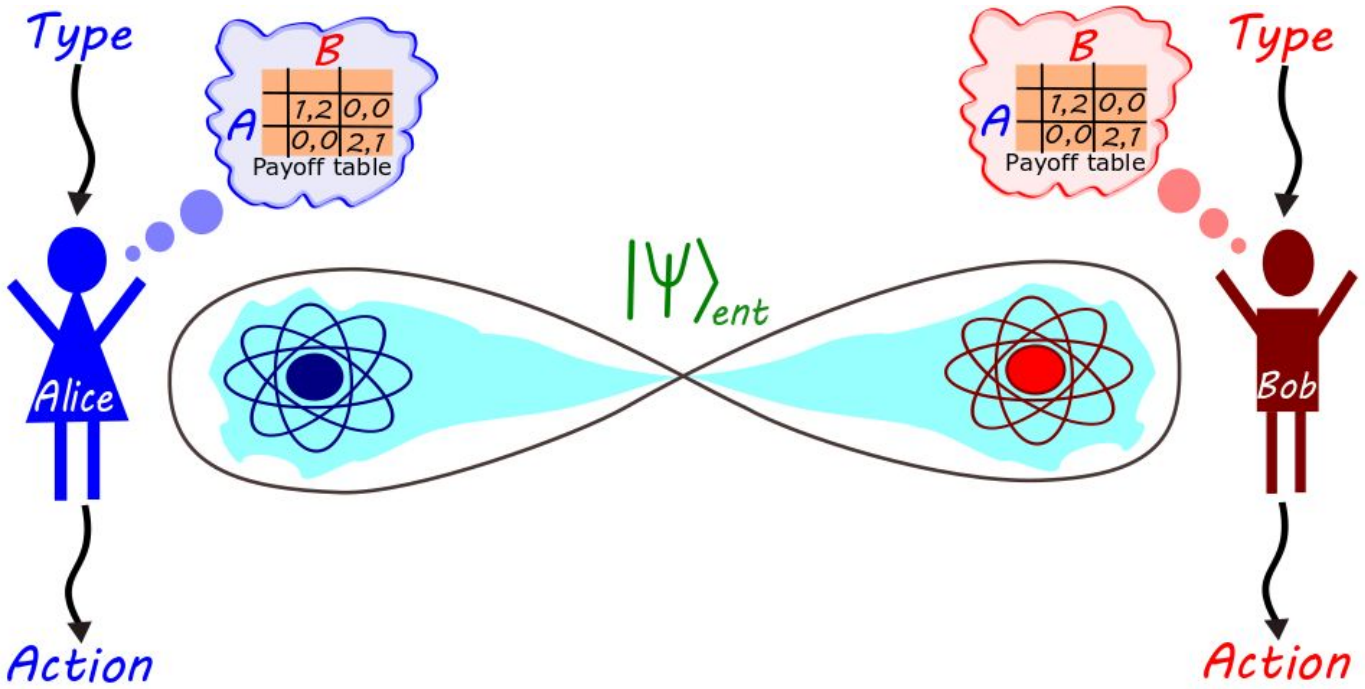

**FIGURE 6.** ***Sn*** **module architecture.**

[2018 - Parallel Implementation of Reinforcement Learning Q-Learning Technique for FPGA]

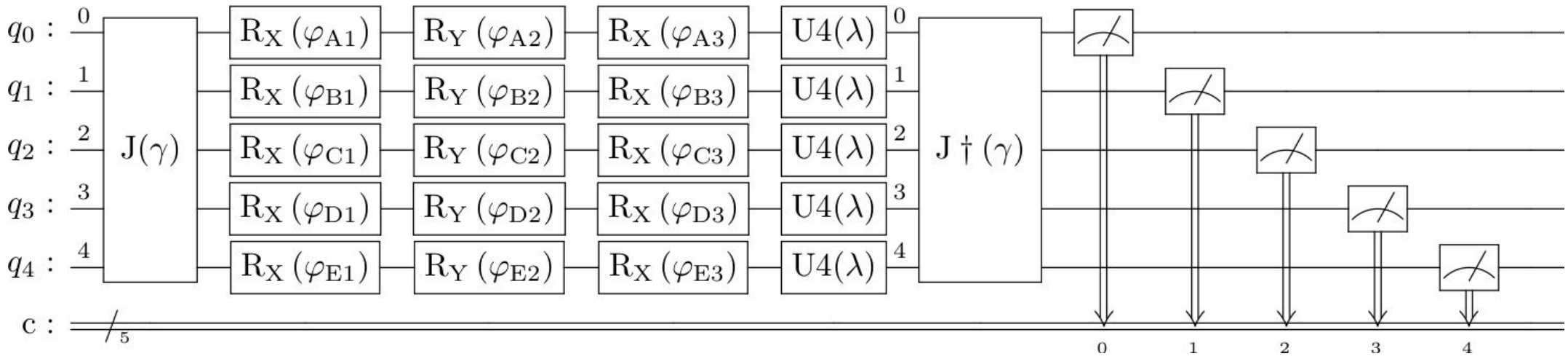
# Quantum Computing



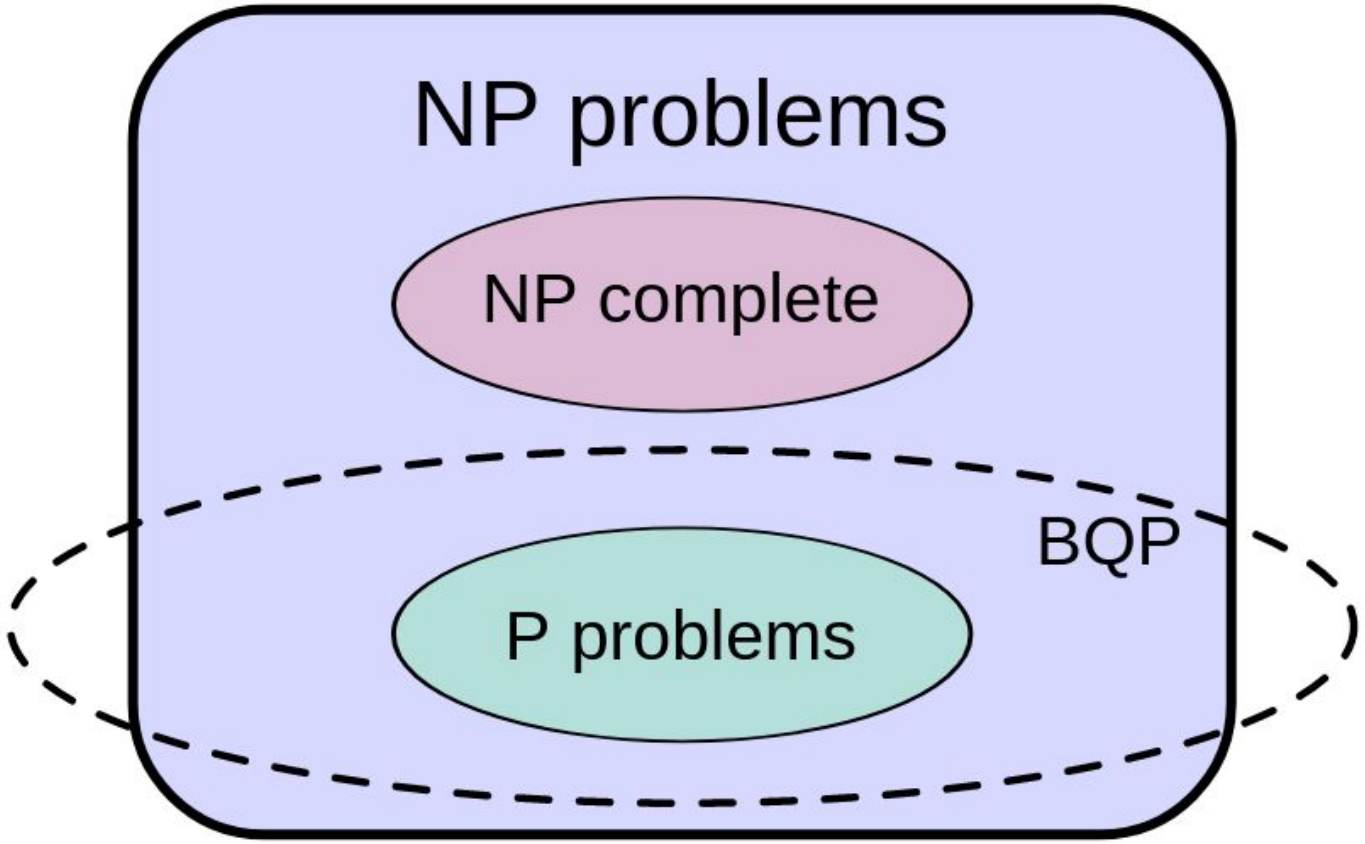
# Quantum Entanglement



# Quantum Circuits



# Quantum Complexity



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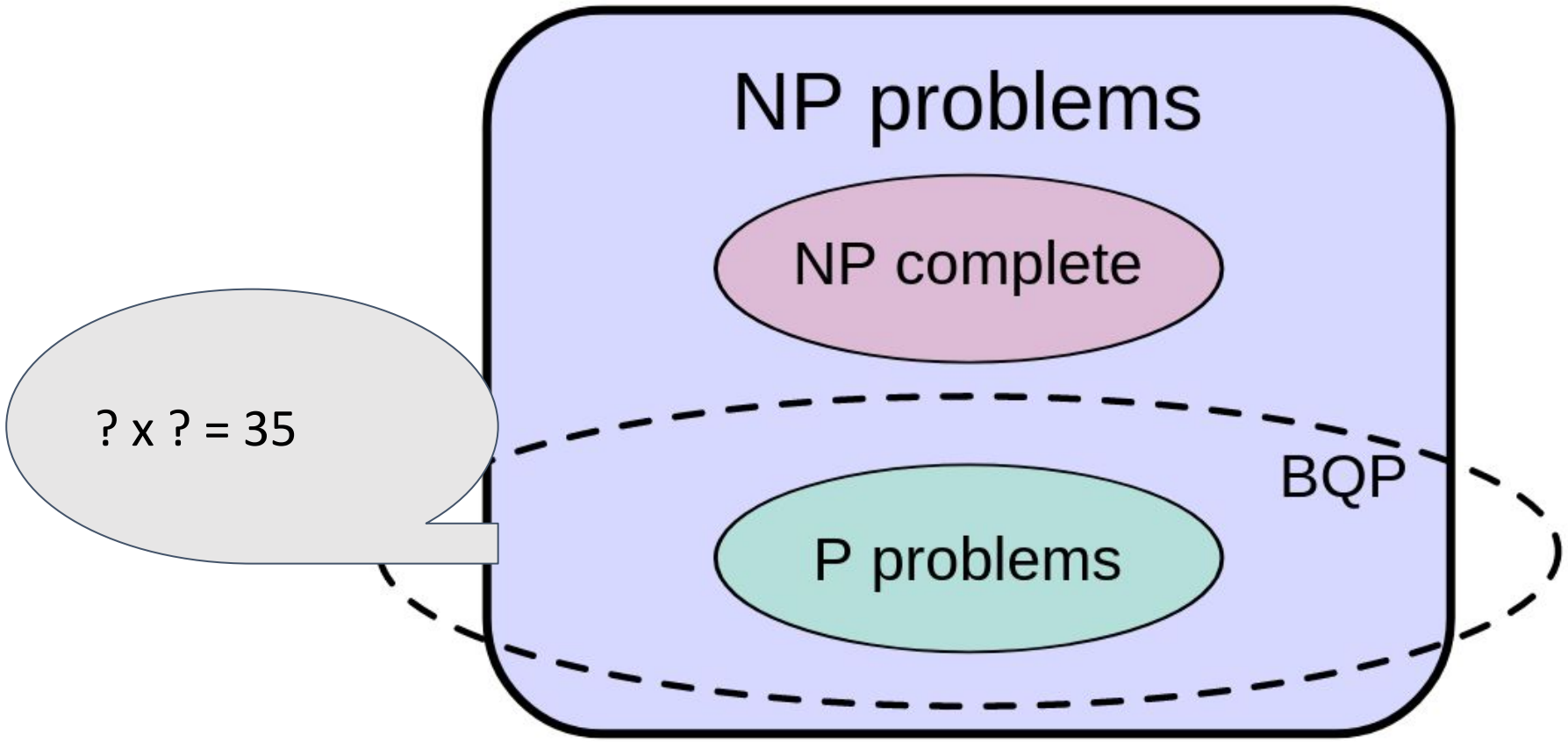

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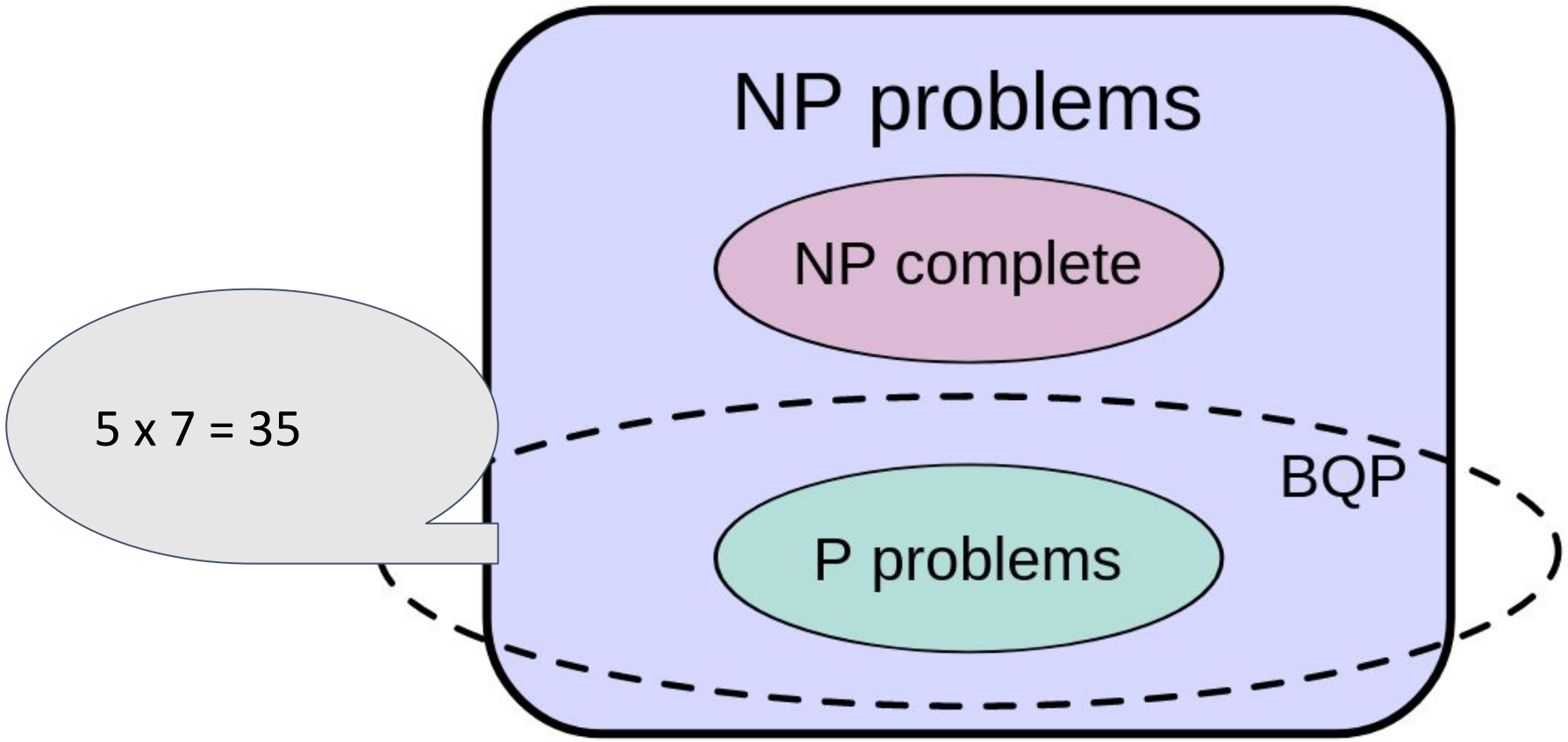

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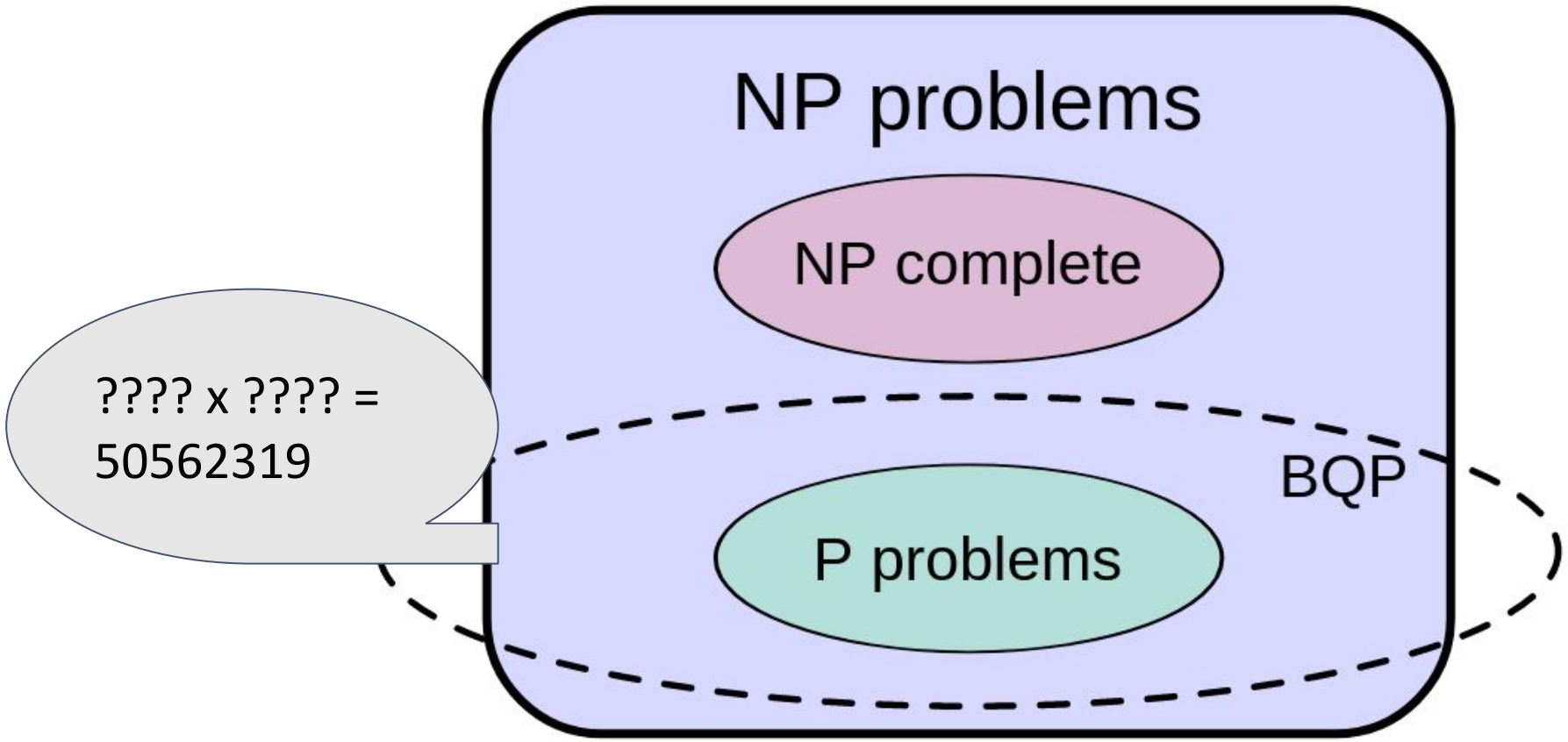

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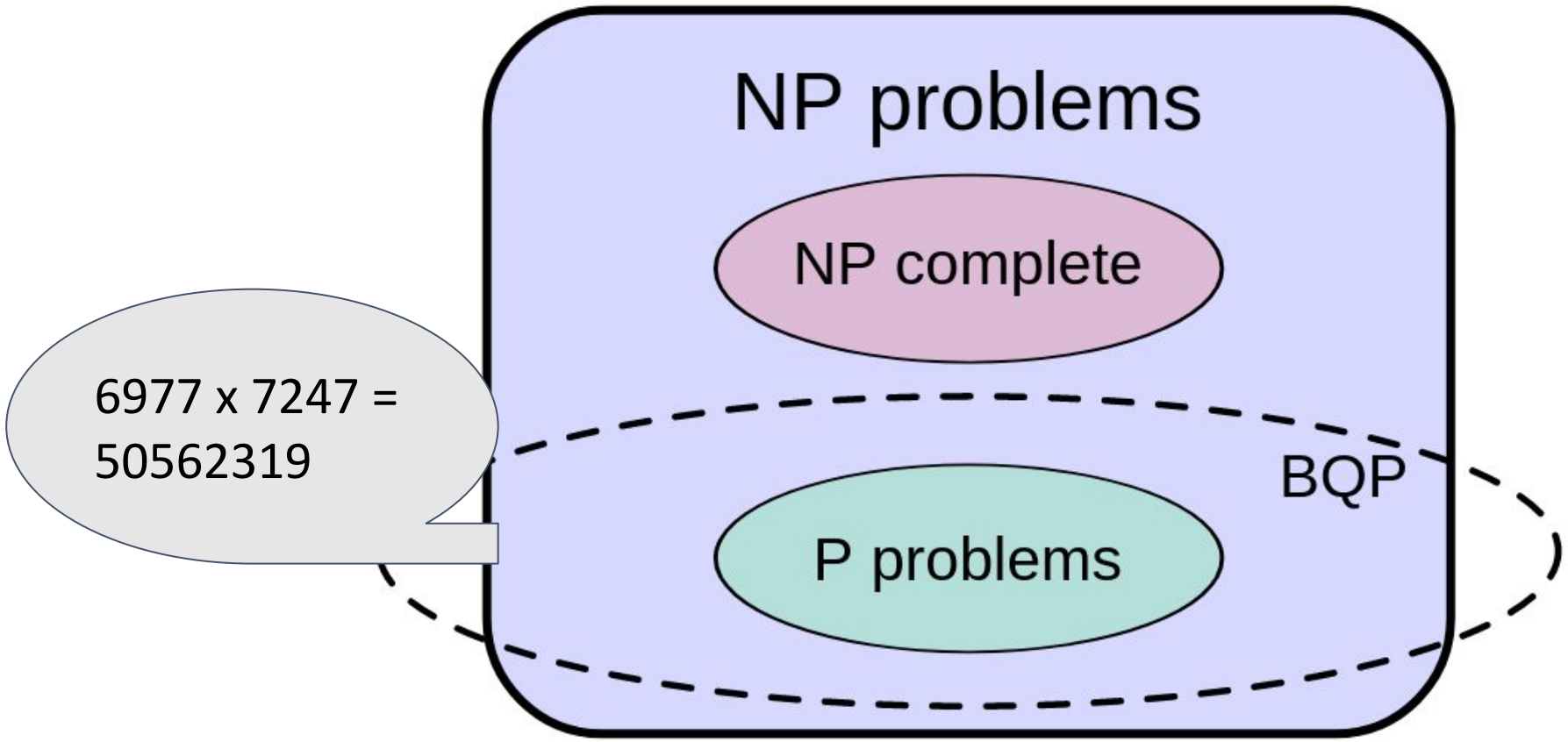
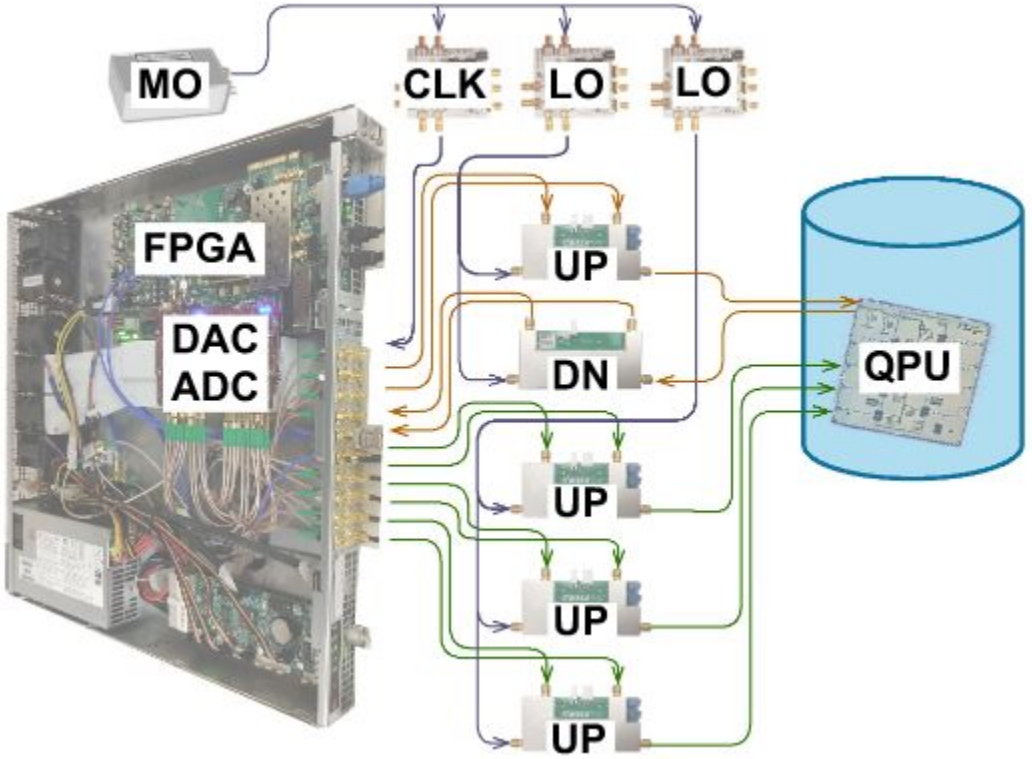


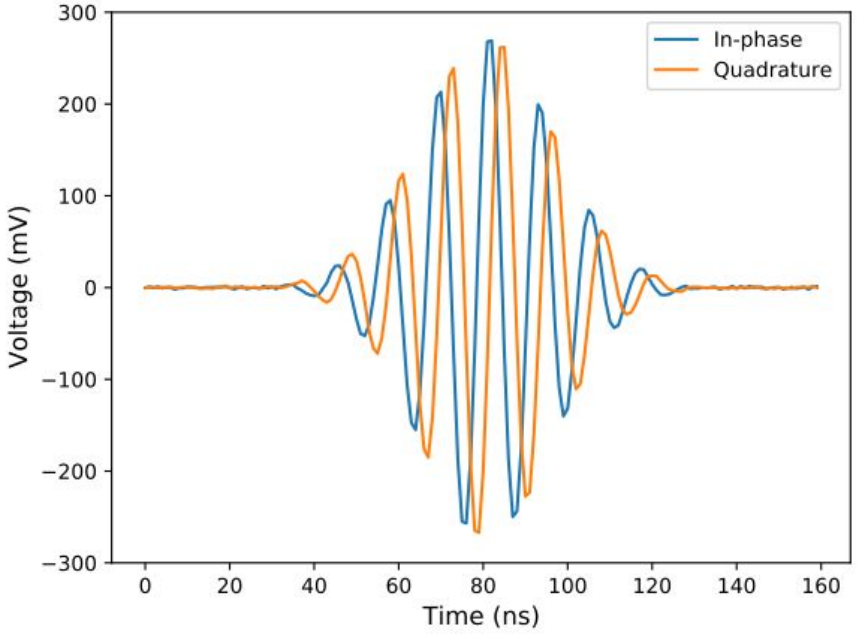
# FPGA for Quantum Computing (Building)



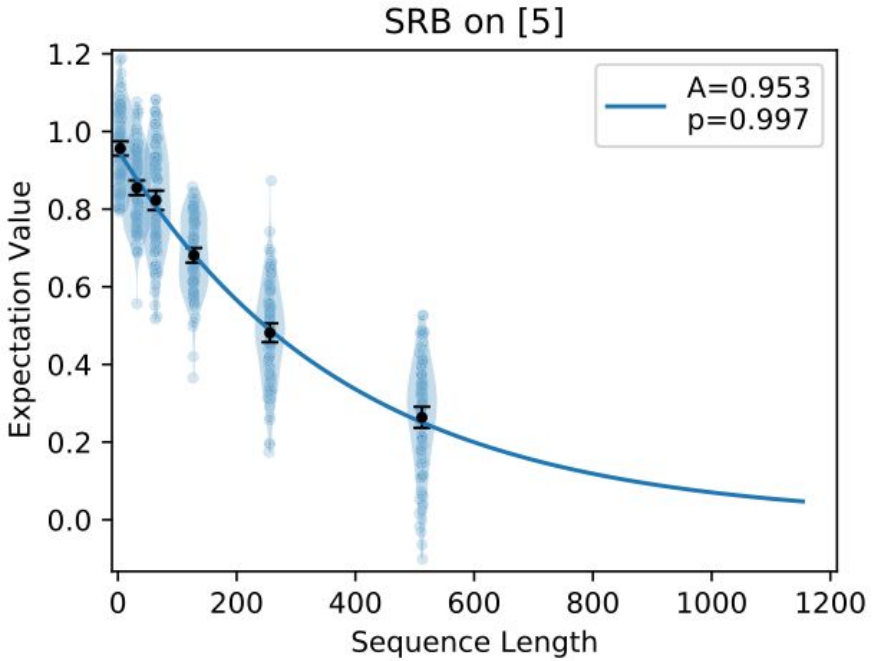

[2021 - FPGA-based control and measurement system for superconducting quantum information processors]

# FPGA for Quantum Computing (Building)

Quantum Gate: set destination, timing, carrier, amplitude and envelope.

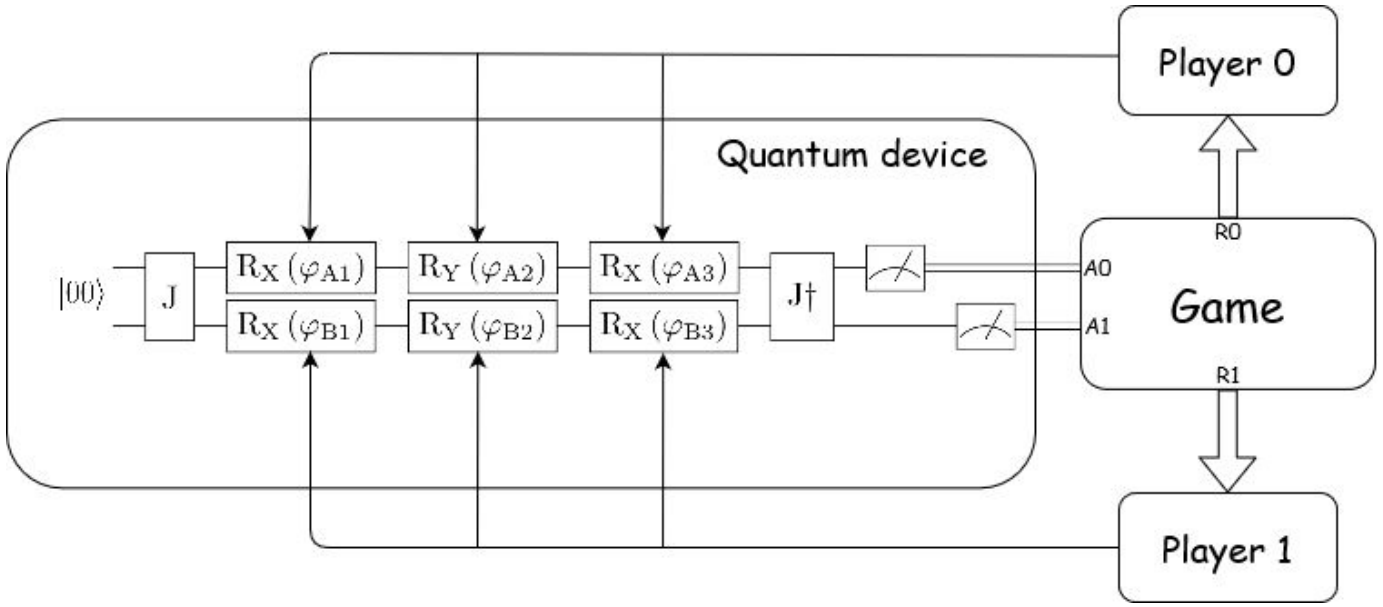



Readout: Measures relaxation time and dephasing time.



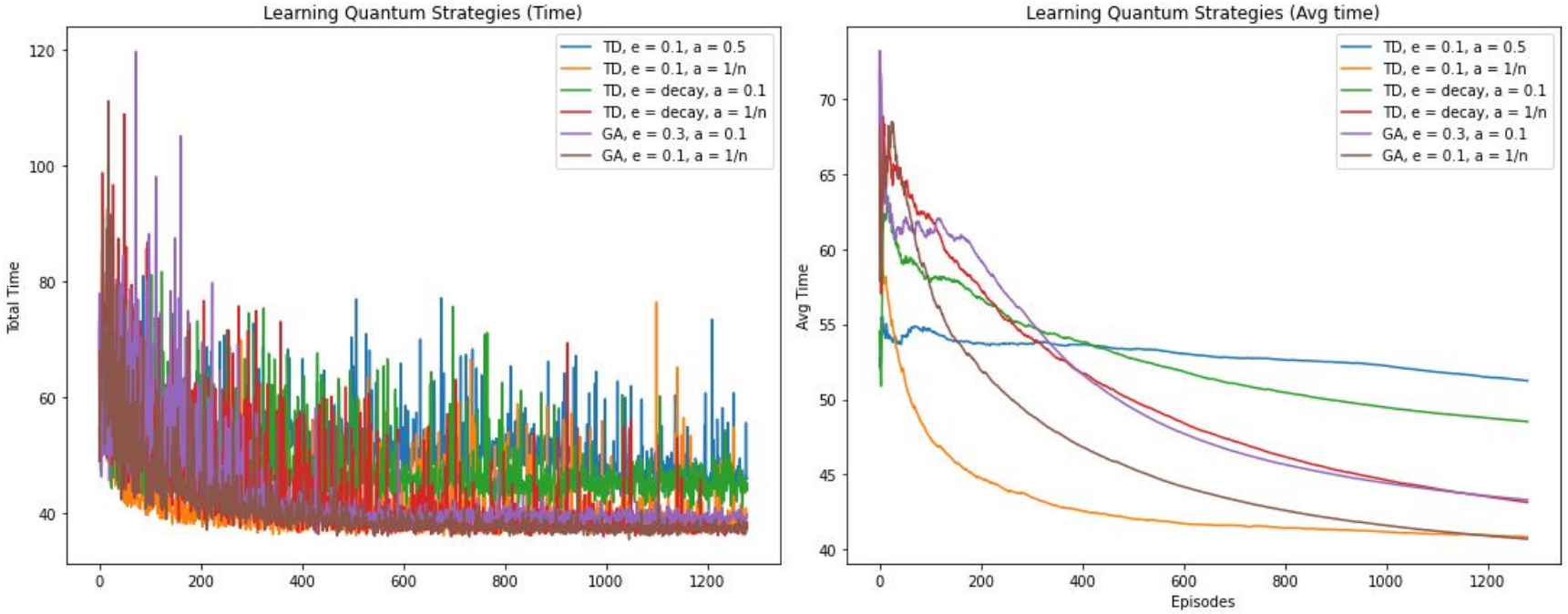

[2021 - FPGA-based control and measurement system for superconducting quantum information processors]

# Reinforcement Learning in Quantum Computing



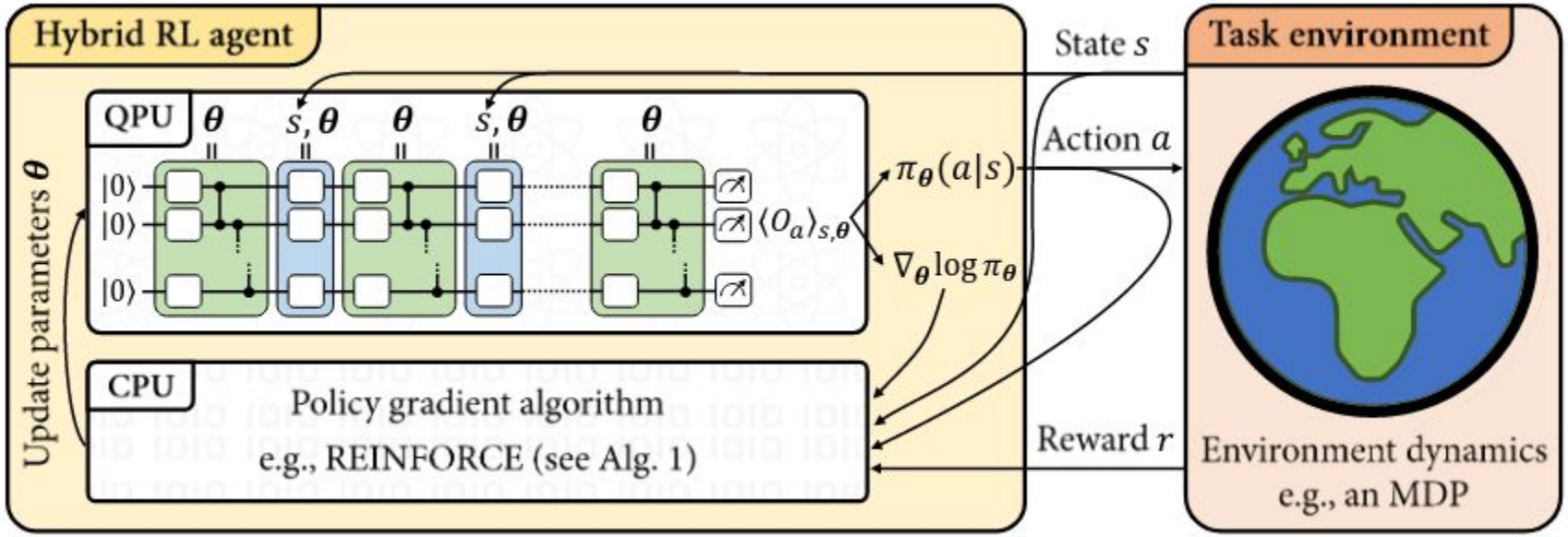

[2022 - Learning Mixed Strategies in Quantum Games with Imperfect Information]

# FPGA for Reinforcement Learning in Quantum Computing (Real-time)



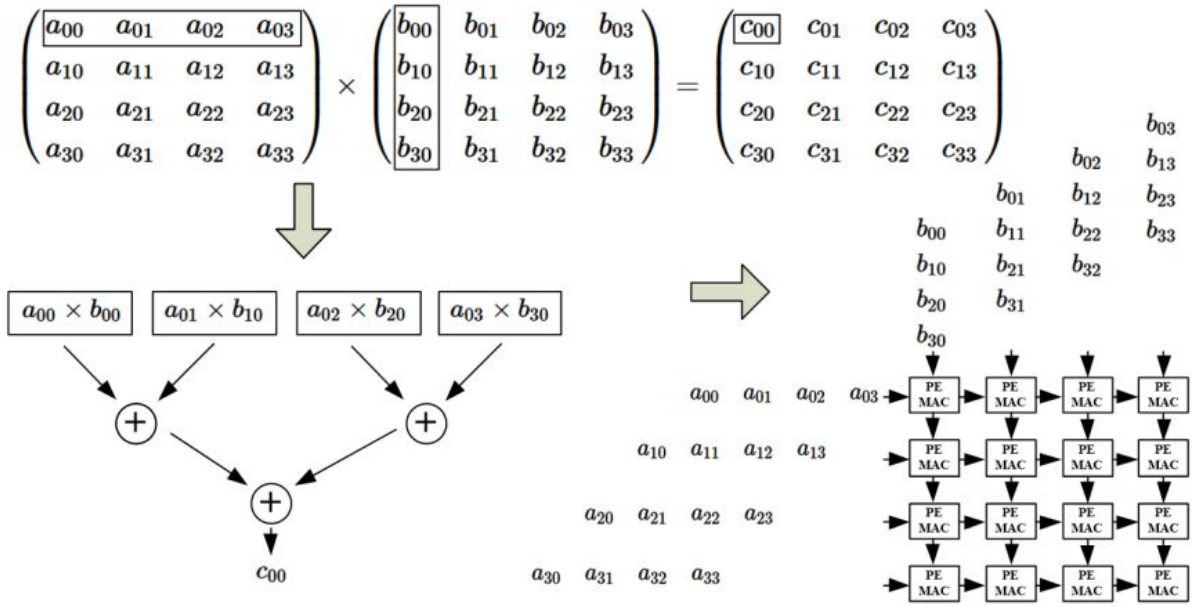

[2022 - Learning-based Protocol for Routing in Quantum Networks]

# Quantum Computing in Reinforcement Learning




[2021 - Parametrized Quantum Policies for Reinforcement Learning]

# FPGA for Quantum Computing in Reinforcement Learning (Simulation)




(b) Systolic array architecture implementing matrix multiplication. Input matrices $A$ and $B$ stream by to produce output matrix $C$ via successive mutiply-accumulate (MAC) operations. Note that $C$ remains in the processing elements (i.e. this is a diagram of an OS architecture). [38].

Figure 2.4: Systolic arrays

[2021 - Tensor Networks for Simulating Quantum Circuits on FPGAs]

# Conclusions

FPGAs can be used:

- to accelerate Reinforcement Learning algorithms.
- to build Quantum Computers.
- in real-time Reinforcement Learning application.
- to simulate Quantum Computers.

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# Thank you!
# Questions?