## **Exploring Biological Neuronal Correlations with Quantum Generative Models**

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#### "Understanding how biological neural networks process information is one of the biggest open scientific questions of our time."





#### "How do brains process information?"





"Exceptional efficiency of biological systems?"

#### "New models for computation?"

### Modeling biological neuronal systems



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#### **Machine Learning Models**



 $y = f_{\theta}(x)$ 

#### **Machine Learning Models**









 $y = f_{\theta}(x)$ 

#### **Machine Learning Models**

#### einstein

# girl with pearl earring



![](_page_6_Picture_4.jpeg)

<u>Output</u> einstein

 $y = f_{\theta}(x)$ 

#### **Generative Learning Models**

![](_page_7_Picture_1.jpeg)

![](_page_7_Picture_2.jpeg)

![](_page_7_Figure_3.jpeg)

![](_page_7_Picture_4.jpeg)

![](_page_7_Picture_5.jpeg)

![](_page_7_Figure_6.jpeg)

![](_page_7_Picture_7.jpeg)

![](_page_7_Picture_8.jpeg)

![](_page_7_Picture_9.jpeg)

![](_page_7_Figure_10.jpeg)

#### **Generative Learning Models**

### einstein + girl with pearl earring

![](_page_8_Figure_2.jpeg)

#### QML

![](_page_9_Figure_1.jpeg)

Pennylane AI https://pennylane.ai/qml/demos/tutorial\_quantum\_natural\_gradient

- expressivity
- interpretability reduced number of parameters

![](_page_9_Picture_6.jpeg)

#### **Exploring Biological Neuronal Correlations with Quantum Generative Models**

![](_page_10_Figure_1.jpeg)

#### Design a quantum generative model that produces neuronal activity indistinguishable from the real biological data!

Hernandes, V., & Greplova, E. (2024). Exploring Biological Neuronal Correlations with Quantum Generative Models. arXiv preprint arXiv:2409.09125.

Hernandes, V., & Greplova, E. (2023, September). Modeling Neuronal Activity with Quantum Generative Adversarial Networks. In 2023 IEEE International Conference on Quantum Computing and Engineering (QCE) (Vol. 2, pp. 330-331). IEEE.

![](_page_10_Picture_5.jpeg)

#### **Quantum Generative Adversarial Model: SpiQGAN**

![](_page_11_Figure_1.jpeg)

Hernandes, V., & Greplova, E. (2024). Exploring Biological Neuronal Correlations with Quantum Generative Models. arXiv preprint arXiv:2409.09125.

Hernandes, V., & Greplova, E. (2023, September). Modeling Neuronal Activity with Quantum Generative Adversarial Networks. In 2023 IEEE International Conference on Quantum Computing and Engineering (QCE) (Vol. 2, pp. 330-331). IEEE.

![](_page_11_Picture_4.jpeg)

#### Our model reproduces both spacial and temporal correlations in neuronal activity with linear number of trainable parameters!

![](_page_12_Figure_1.jpeg)

![](_page_12_Figure_3.jpeg)

#### Our model reproduces both spacial and temporal correlations in neuronal activity with linear number of trainable parameters!

![](_page_13_Figure_1.jpeg)

Hernandes, V., & Greplova, E. (2024). Exploring Biological Neuronal Correlations with Quantum Generative Models. arXiv preprint arXiv:2409.09125.

![](_page_13_Picture_3.jpeg)

#### • QML: Many open Q's

- Interesting applications?
- to train
- Let's explore QML for compact, more energetically efficient models!

• Challenging neuroscience task: QML is successful and cheaper

![](_page_14_Picture_6.jpeg)