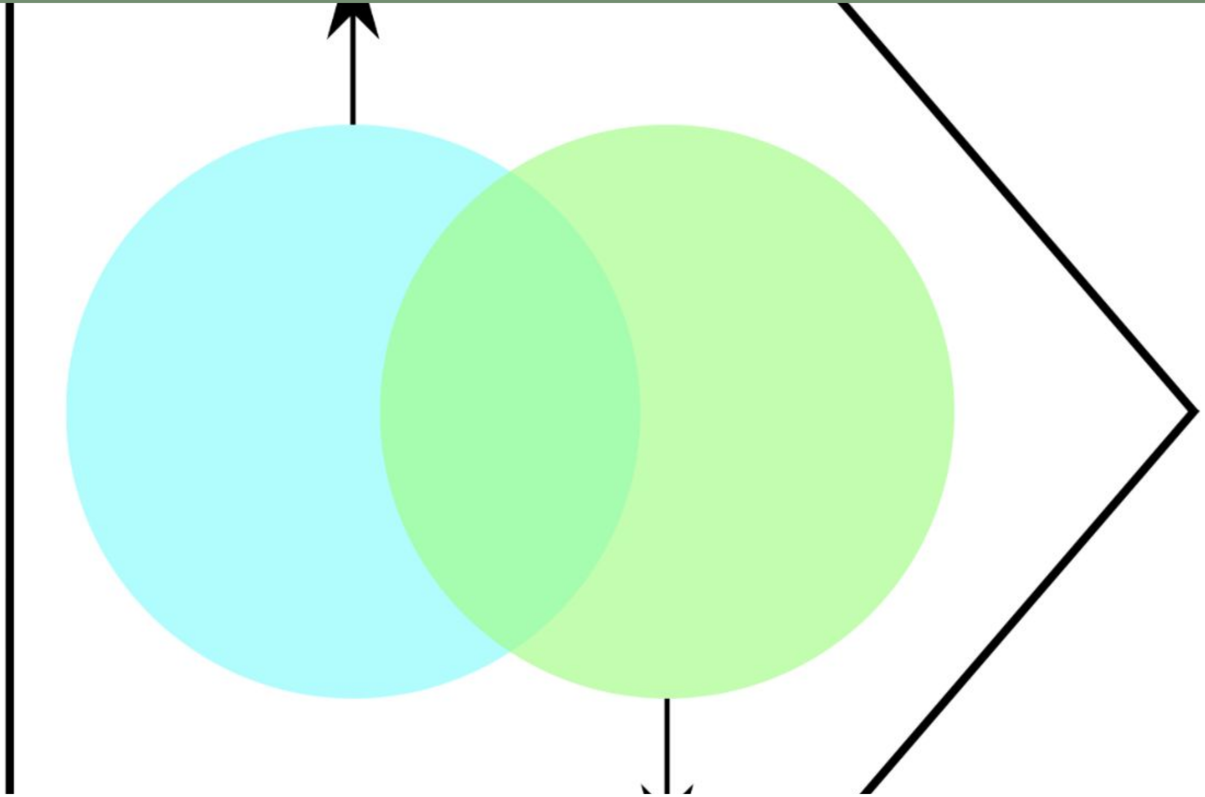

# Grand unification of quantum algorithms

Quantum Singular Value Decomposition

# I will shamelessly steal from this

*Excellent tutorial article on PRX Quantum*

PRX QUANTUM **2,** 040203 (2021)

Tutorial

## Grand Unification of Quantum Algorithms

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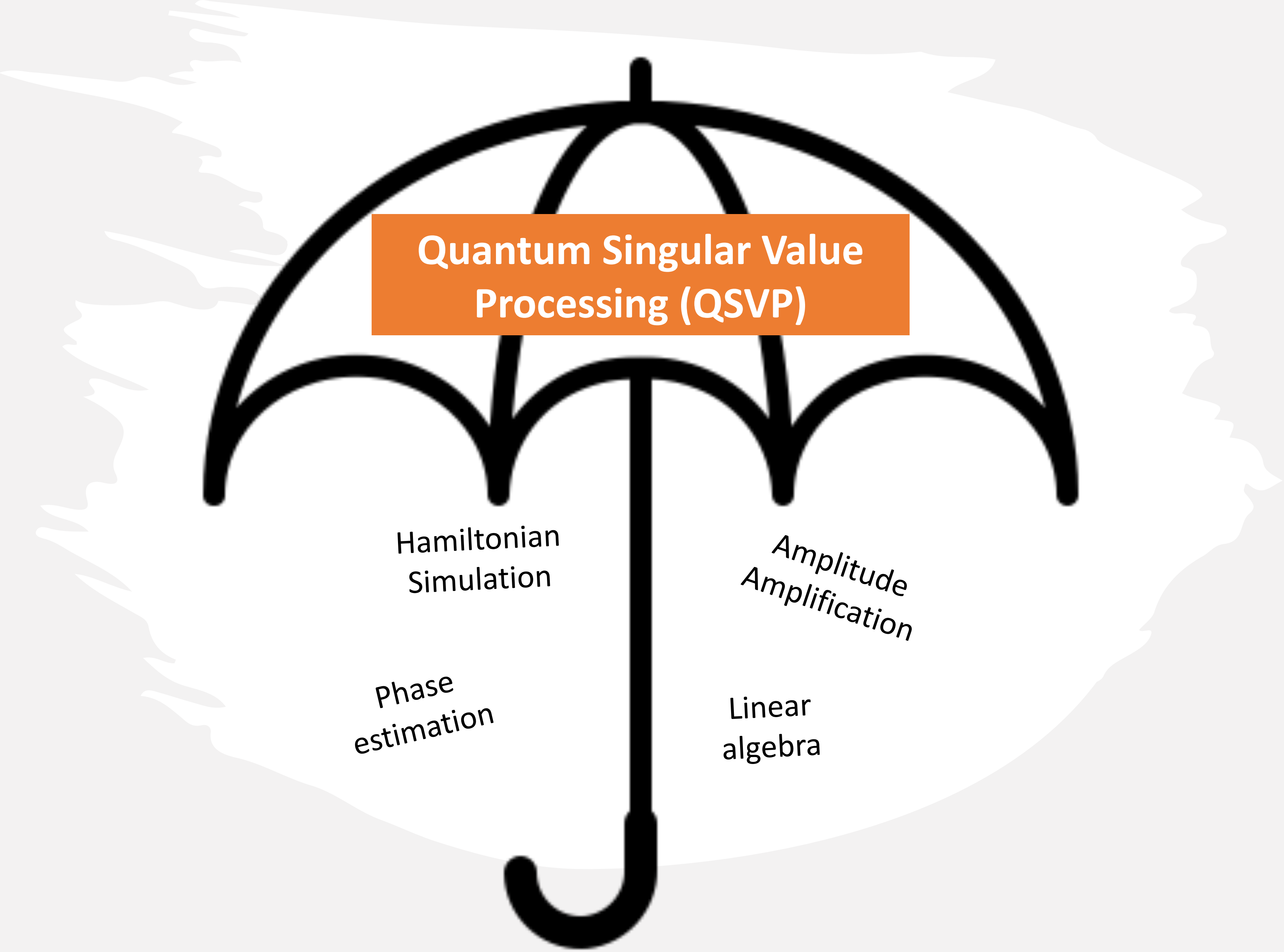
Quantum algorithms offer significant speed-ups over their classical counterparts for a variety of problems. The strongest arguments for this advantage are borne by algorithms for quantum search, quantum phase estimation, and Hamiltonian simulation, which appear as subroutines for large families of composite quantum algorithms. A number of these quantum algorithms have recently been tied together by a novel technique known as the quantum singular value transformation (QSVT), which enables one to perform a polynomial transformation of the singular values of a linear operator embedded in a unitary matrix. In the seminal GSLW'19 paper on the QSVT [Gilyén *et al.*, ACM STOC 2019], many algorithms are encompassed, including amplitude amplification, methods for the quantum linear systems problem, and quantum simulation. Here, we provide a pedagogical tutorial through these developments, first illustrating how quantum signal processing may be generalized to the quantum eigenvalue transform, from which the QSVT naturally emerges. Paralleling GSLW'19, we then employ the QSVT to construct intuitive quantum algorithms for search, phase estimation, and Hamiltonian simulation, and also showcase algorithms for the eigenvalue threshold problem and matrix inversion. This overview illustrates how the QSVT is a single framework comprising the three major quantum algorithms, suggesting a *grand unification* of quantum algorithms.

DOI: 10.1103/PRXQuantum.2.040203

# What are some well-known quantum algorithms?


Quantum Singular Value Processing (QSVP)
Hamiltonian Simulation
Amplitude Amplification
Phase estimation
Linear algebra

# What does Quantum Singular Value Processing actually do?

# What does QSVP need?

# Roadmap

<u>This week</u>:

Quantum signal processing (QSP), i.e. making polynomials out of $X$ and $Z$ rotations

<u>Next week</u>:

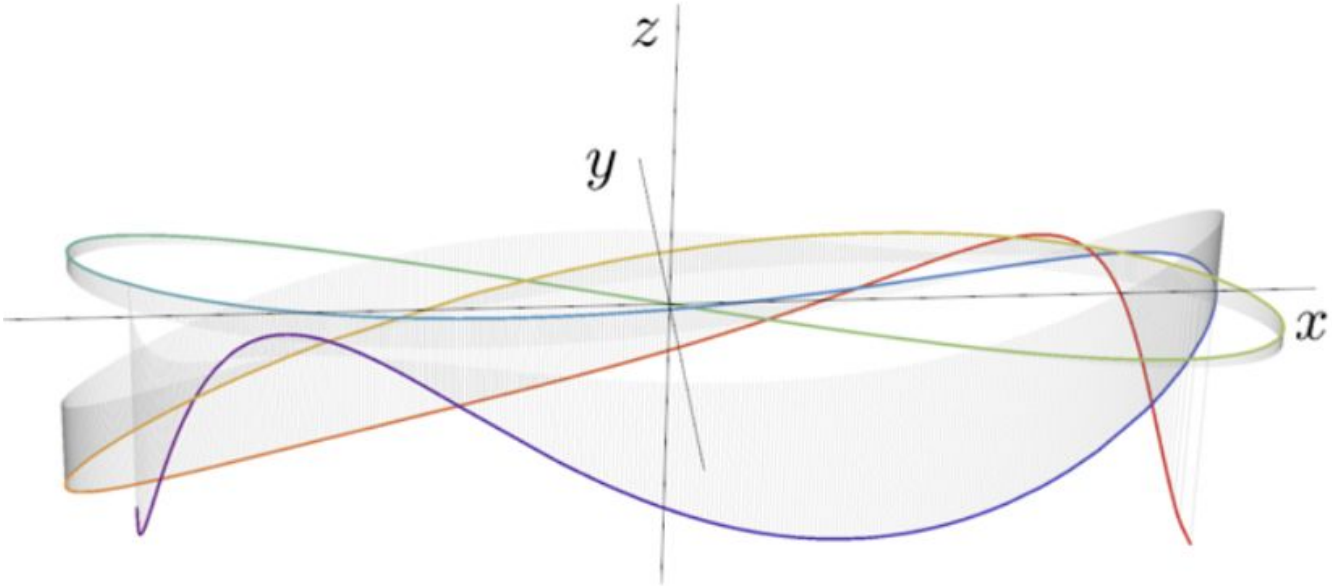
Qubitization (hopefully), i.e. making QSP possible on more general spaces

# Switch to notebook here

# Let’s try QSP!

# Summary

- *Quantum Singular Value Transformations* generalize many existing quantum algorithms
- *Quantum Signal Processing,*a necessary ingredient, which constructs polynomials by interleaving rotation gates about different axes
- We did an actual QSP calculation!




Quantum 3, 163 (2019).

# Additional resources

Original paper by Low & (Isaac) Chuang: arXiv:1610.06546v3

- Focuses on application for Hamiltonian simulation

Guang Hao Low's thesis

- More elaboration on the above.

Quantum Singular Value Processing (QSVP): arXiv:1806.01838v1

- Generalizes Quantum Signal Processing (QSP) of original work

The tutorial article: https://journals.aps.org/prxquantum/pdf/10.1103/PRXQuantum.2.040203