Gravitational Wave Data Analysis on a Quantum Computer

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Abstract

Classical data analysis requires computational efforts that become intractable in the age of Big Data [1]. An essential task in time series analysis is the extraction of physically meaningful information from a noisy time series. One algorithm devised for this very purpose is singular spectrum decomposition (SSD), an adaptive method that allows for the extraction of narrow-banded components from non-stationary and non-linear time series [2]. The main computational bottleneck of this algorithm is the singular value decomposition (SVD). Quantum computing could facilitate a speedup in this domain through superior scaling laws [3]. We propose quantum SSD by assigning the SVD subroutine to a quantum computer. The viability for implementation and performance of this hybrid algorithm on a near term hybrid quantum computer are investigated. In this work we show that by employing randomised SVD, we can impose a qubit limit on one of the circuits to improve scalability. Using this, we perform quantum SSD on GW150914, the first detected gravitational wave event.

References

[1] Couvares, Peter, et al. "Gravitational Wave Data Analysis: Computing Challenges in the 3G Era." *arXiv preprint arXiv:2111.06987* (2021).

[2] Bonizzi, Pietro, et al. "Singular spectrum decomposition: A new method for time series decomposition." *Advances in Adaptive Data Analysis* 6.04 (2014)

[3] Wang, Xin, Zhixin Song, and Youle Wang. "Variational quantum singular value decomposition." *Quantum* 5 (2021)

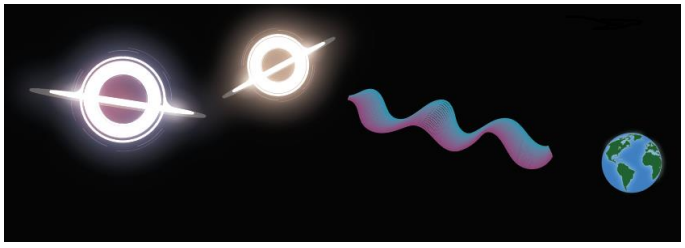

Figure 1: Black hole binaries are a source for gravitational waves, which can be measured on Earth with high sensitivity detectors such as LIGO-Virgo. Analysis of such signals yields great insight into gravitational physics.

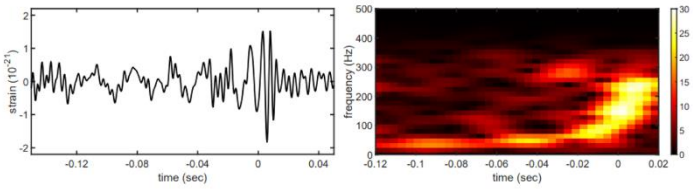

Figure 2: Gravitational wave GW150914, with its associated spectrogram, after being filtering through quantum singular spectrum decomposition. A waveform is obtained that has favourable properties for data analysis purposes.