Parameter estimation of gravitational waves with a quantum metropolis algorithm

Gabriel Escrig Mas,* Roberto Campos, Pablo A. M. Casares, and M. A. Martin-Delgado
Universidad Complutense de Madrid

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After the first detection of a gravitational wave in 2015, the number of successes achieved by this innovative way of looking through the Universe has not stopped growing. However, the current techniques for analysing this type of events present a serious bottleneck due to the high computational power they require. In this talk, we explore how recent techniques based on quantum algorithms could surpass this obstacle [1]. For this purpose, we propose a quantization of the classical algorithms used in the literature for the inference of gravitational wave parameters [2] based on the well-known quantum walks technique applied to a Metropolis–Hastings algorithm. Finally, we develop a quantum environment on classical hardware, implementing a metric [3] to compare quantum versus classical algorithms in a fair way. We further test all these developments in the real inference of several sets of parameters of all the events of the first detection period GWTC-1 [4] and we expose a polynomial advantage in the quantum algorithms, thus setting a first starting point for future algorithms.

[1] Gabriel Escrig et al, Class. Quantum Grav., 40 (2023) 045001.

[2] Christensen N and Meyer R, Rev. Mod. Phys., 94 (2022) 025001.

[3] Lemieux J, Heim B, Poulin D, Svore K and Troyer M, Quantum, 4 (2020) 287.

[4] Alexander Nitz et al, arXiv pre-print:2112.06878, (2021)

* gescrig@ucm.es

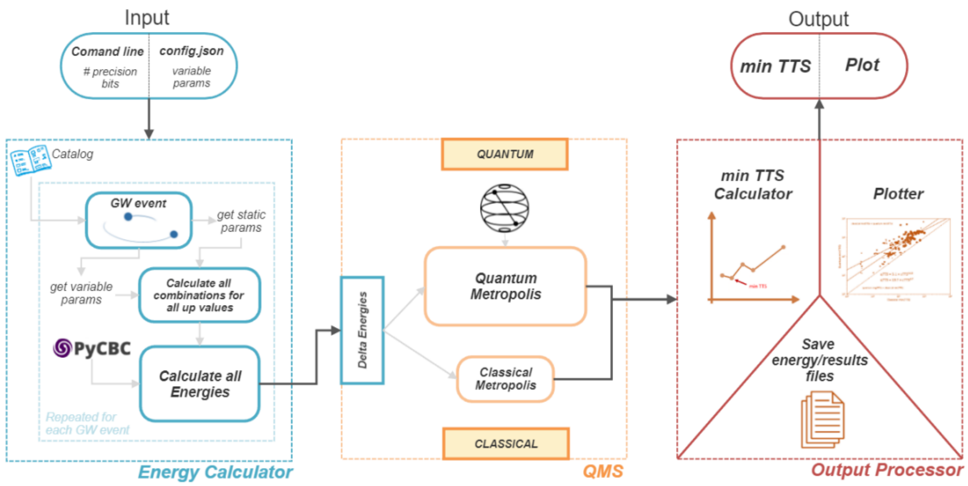

FIG. 1. Flowchart of the algorithm implemented. This algorithm consists of three stages: a first stage where the energies are calculated with the help of the GW library PyCBC. A second stage, where the two Metropolis–Hastings algorithms are executed, the quantum algorithm being programmed from the Qiskit library, and a third stage where the results are stored and the values for the chosen figure of merit are calculated. Finally, the value of min total time to solution (TTS) is obtained for each of the classical/quantum parts for later comparison.

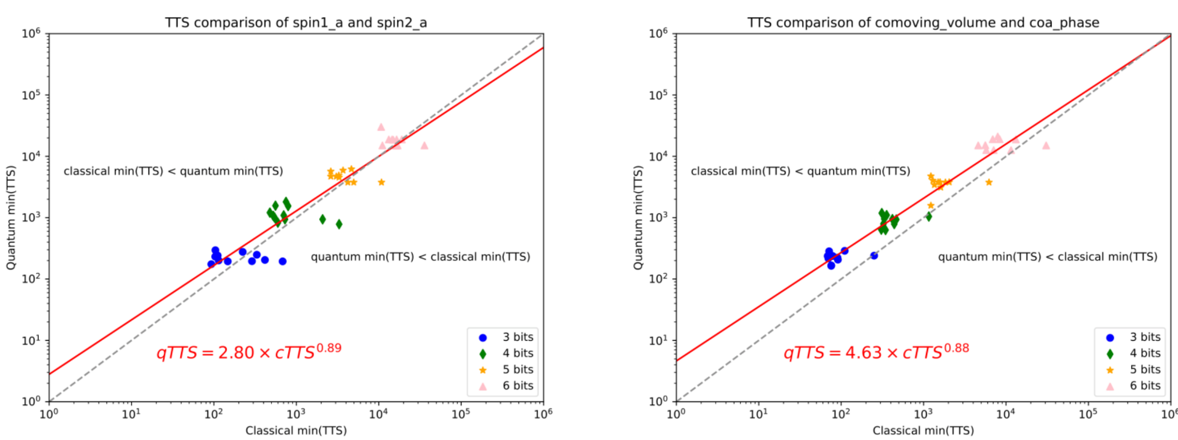

FIG. 2. Comparison of the minimum value of the classical and quantum TTS achieved for the 2-parameter inference simulations. Left the dimensionless spin-magnitude of the larger and smaller object have been inferred. Right the comoving volume and the coalescence phase have been inferred. All results have been obtained for 3–6 bits of precision. A polynomial advantage can be observed in the quantum algorithm.