A variational toolbox for analog quantum simulators

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Current experimental quantum devices do not meet the requirements for building fault-tolerant quantum computers, but they still can be used to address many-body problems as analogue quantum simulators. Different physical platforms, like superconducting circuits [1], trapped ions [2], and cold atoms [3,4], have different interactions between their components. However, the systems simulated are constrained by the type of interactions that can be engineered in the platform, limiting the range of models that can be simulated.

Variational methods have been suggested as a way to go beyond this limitation [5]. Among the different proposals, Variational Quantum Time Evolution algorithms (VarQTE) can perform either real- or imaginary-time evolution within the same framework [6]. In this work, we propose to use this variational approach to fully harness the interactions present in analogue quantum simulators.

In the first part of the talk, we demonstrate how the long-range interactions present in certain analog quantum simulators can be used to solve some of the limitations of VarQTE algorithms [5]. Then, in the second part, we focus on fermionic quantum simulators and show how these algorithms can be used to prepare ground states of fermionic models in more efficient ways than standard methods (either because the target interactions cannot be efficiently generated or because adiabatic methods fails while variational ones do not). We suggest possible ways to implement our protocols considering a finite measurement budget and show how their convergence can be accelerated using techniques inspired from classical methods, such as the QLanczos algorithm [7].

In summary, these results demonstrate that a careful combination of classical and quantum resources provide analog quantum simulators with a new set of tools that fully leverage their current capabilities.

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