# A variational toolbox for analog quantum simulators

**Cristian Tabares**[1]
J. Schneider[1], A. Muñoz de las Heras[1], L. Tagliacozzo[1], D. Porras[1], D. González-Cuadra[2,3] and A. González-Tudela[1]
[1]*Institute of Fundamental Physics IFF-CSIC, Calle Serrano 113b, 28006 Madrid, Spain*
[2]*Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria*
[3]*Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria*
cristian.tabares@csic.es

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 VarQTE algorithms can be used to prepare ground states of exotic 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). These results provide analog quantum simulators with a new set of tools that fully leverage their current capabilities.

References

[1] X. Zhang et al., Science **379**, 278-283 (2023).
[2] C. Kokail et al., Nature **569**, 355–360 (2019).
[3] S. Ebadi et al., Nature **595**, 227–232 (2021).
[4] J. Argüello-Luengo et al., Nature **574**, 215–218 (2019).
[5] C. Tabares et al., Phys. Rev. Lett. **131**, 073602 (2023).
[6] X. Yuan et al., Quantum **3**, 191 (2019).

Figures

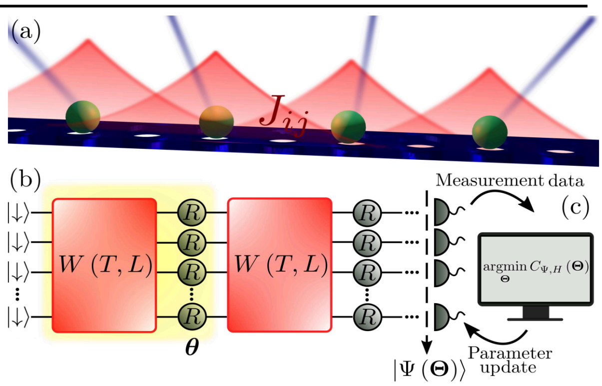


**Figure 1:** (a) Schematic depiction of atoms coupled to a waveguide, an analog quantum simulator with long-range interactions. (b,c) Quantum-classical algorithm using this interaction.