TouQan: Towards a Useful Quantum Advantage

QUANTERA

The project

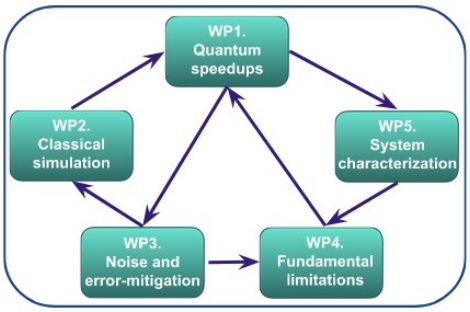
In recent years, the field of quantum technologies has experienced significant growth. During this expansion, **quantum simulators** have emerged as one of the most experimentally advanced platforms. There is a growing consensus among physicists that quantum simulators have already achieved a so-called **quantum advantage**. However, these results have received considerably less attention and scrutiny than similar claims made for digital quantum computers.

TouQan aims to bridge the gap in our understanding of potential quantum advantages in quantum simulators. Firstly, we will advance our knowledge of the **computational power** of simulators from a **mathematically rigorous** perspective and will find ways of characterizing it, including the impact of hardware noise. Secondly, we will examine under which conditions classical computers can effectively simulate quantum simulators to narrow down when they do not offer significant advantages. By doing so, a clearer picture of these devices' **computational power** will emerge.

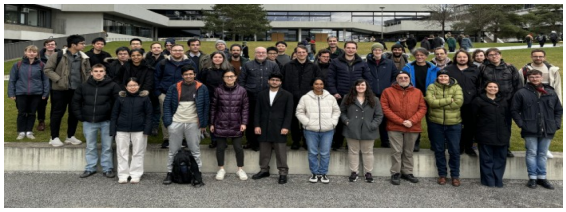
The interdisciplinary nature of this project requires the use and development of advanced tools at the intersection of **computer science**, **physics**, and **mathematical physics**. Our consortium comprises five ambitious early-career researchers with excellent track records based in various European countries. This collaborative effort will foster increased cooperation among European nations on a timely topic, ultimately bolstering the development of quantum simulators and enhancing our understanding of their computational power and, in particular, of how they offer the widely-sought quantum advantage.

Goals and activities

- **WP1**: Development of efficient protocols to be executed in the quantum simulators, with theoretical evidence for hardness. (e.g. arXiv:2411.04885)
- **WP2:** Construction of classical simulation schemes for the tasks of WP1, with provable efficiency guarantees in restricted regimes.
- **WP3:** Elucidate fundamental limitations of the power of quantum computational schemes.(e.g. arXiv:2410.19903, arXiv:2501.09339)
- **WP4:** Characterize the noise that might appear in practical settings, find how to mitigate it, and analyze their effect on the quantum and classical simulability. (e.g. arxiv:2501.13050)
- **WP5:** Finding efficient ways of verifying the quantum simulations.



Kick-off @TUHH Hamburg, 12-14th June 24

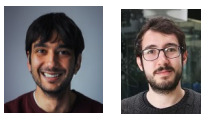


Many-body workshop Tuebingen, 16-20th Dec 24

TouQan Meeting @Cambridge U., 10-14th Feb 25

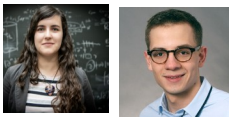
Consortium

Alvaro M. Alhambra + Matteo Scandi (Postdoc)
WP2 - Spain (Coordinator)



Instituto de Física Teórica UAM CSIC

Angela Capel + Tim Moebus (Postdoc)
WP4 - Germany



EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Martin Kliesch + Özgün Kum (PhD Student)
WP5 - Germany

TUHH Hamburg University of Technology

Michal Oszmaniec + Marcin Kotowski (Postdoc)
WP3- Poland

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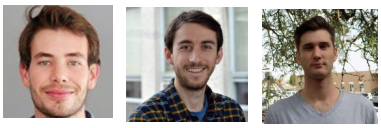
Daniel Stilck-Franca
Mischa Woods + Sam Slezak (postdoc)
WP1 - France



Inria