ETNA4Ryd - Enhancing Tensor Network Approaches for Rydberg Atom Quantum Simulators

Recent experiments with ultracold atoms, trapped ions, Rydberg atoms, and superconducting circuits succeeded in realizing quantum many-body states at unprecedented sizes and thus investigating their static and dynamical properties. These achievements have boosted the search for protocols to observe exotic phases of matter in quantum simulators and to implement quantum computations unaffordable for classical supercomputers. I aim to investigate Rydberg-atom platforms, improving their efficiency for future quantum simulation and computation tasks, motivated by their versatility and manipulation capability. Classical numerical simulations are fundamental to developing quantum simulators, engineering efficient experimental protocols, and benchmarking the results. Still, an exact representation for large quantum many-body states is highly inefficient and impossible to achieve for the sizes available in current experiments. I will exploit advanced numerical tensor network methods to simulate the out-of-equilibrium properties of highly constrained quantum phases, as topological spin glasses and quantum scars, recently realized on Rydberg-atom high-dimensional lattices. Indeed, tensor networks are a balanced approximation between accuracy and computational resources and are the ideal set of tools to investigate constrained regimes in quantum many-body systems. Realizing this project first at the Lukin Quantum Optics Group at Harvard University and then at theQuantum Theory Group at Padua University, I will access worldleading experimental and numerical expertise to perform cutting-edge analytical, numerical, and experimental investigations on Rydberg atom platforms. In addition, I will acquire experiment modeling expertise and apply them at the near-future quantum computation laboratory at Padua University. This project is aligned with the Quantum Technologies Flagship, making me valuable for future innovative research on competitive quantum technologies applications.

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