Physikalisches Kolloquium **Physics Colloquium**

Einladung **Invitation**

Monday, 02 February 2026

Lecture Hall N24/H13, at 16:15
Coffee and cookies will be served in front of the lecture hall from 16:00

Certificate-backed Optimization as a Microscope for Quantum Many-Body Physics

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Quantum devices are reaching sizes where they can generate rich many-body behavior that we cannot faithfully simulate on a classical computer. This is exciting, but it also creates a practical problem: if we cannot calculate in detail what the device should do, how do we trust its output? And, for physics, how do we identify which ingredients of the system are responsible for the observed behavior, rather than relying on heuristic extrapolations?

In this colloquium, I will describe an approach that turns optimization into a tool for making reliable, checkable statements about many-body quantum systems. The key output is a *certificate*: a short proof that a claimed bound is correct, which can be verified independently. Importantly, certificates can provide more than a single number. For instance, a certificate may prove that for all states with sufficiently low energy, a given observable must lie within a specific interval. In this sense, certificates act like a microscope: they do not only tell us what is true, but also reveal which local constraints, symmetries, or algebraic relations are enforcing it, and they indicate what is missing when a stronger conclusion is out of reach.

I will illustrate the idea with the concrete example of spectral gaps in frustration-free spin systems. A spectral gap is an energy separation above the ground state that often underpins the stability of phases and controls how hard it is to prepare states adiabatically. I will explain how one can build a systematic ladder of semidefinite programmes that produces increasingly strong, rigorous lower bounds on the gap, improving on traditional finite-size tests and succeeding in parameter regimes where those tests may fail. The broader message is that certificate-backed methods can turn limited information into trustworthy conclusions, while also teaching us which physical mechanisms are responsible for them.

Host: Prof. Dr. Joachim Ankerhold, Institute of Complexe Quantum Systems

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