Large Scale Quantum Simulations Using Ultracold Atomic Gases in Optical Lattices

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More than 30 years ago, Richard Feynman outlined the visionary concept of a quantum simulator for carrying out complex physics calculations. Today, his dream has become a reality in laboratories around the world. In my talk I will focus on the remarkable opportunities offered by ultracold quantum gases trapped in optical lattices to address fundamental physics questions ranging from condensed matter physics over statistical physics to high energy physics with table-top experiments. To date, ultracold atoms provide the only setting for quantum simulations in which 'quantum supremacy', i.e. the ability to simulate settings beyond the ability of classic supercomputers.

I will show how it has now become possible to image and control quantum matter with single atom sensitivity and single site resolution, thereby allowing one to directly image individual quantum fluctuations of a many-body system, to directly reveal antiferromagnetic order in the fermionic Hubbard model or hidden topological order and exotic forms of magnetic ordering that can now, for the first time, be directly detected in experiments. In addition, I will discuss our recent experiments on novel *many-body localised states of matter that challenge our understanding of the connection between statistical physics and quantum mechanics at a fundamental level. Finally, I will discuss our new experiments on Rydberg dressed quantum gases in which controlled coherent long-ranged interactions can be implemented.*