COVER IMAGE

Before the advent of digital computers, sophisticated orreries were used to predict the positions and motions of astronomical bodies. Now quantum simulators hold the promise of providing insight into the behaviour and properties of complex quantum systems, in situations where classical computers reach their limits. Foreground image: © Michael Ventura/Alamy. Background image: © Immanuel Bloch/MPQ.

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Quantum simulation

Richard Feynman put it in memorable words: “Nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical, and by golly it’s a wonderful problem, because it doesn’t look so easy.”

Simulating one quantum system using another, more controllable one has turned out to be not so easy, indeed. But much progress has been made since 1981, when Feynman delivered his seminal lecture ‘Simulating Physics with Computers’. The tremendous advances in isolating, manipulating and detecting single quantum systems — particularly in the past decade or so — mean that physical implementations of ‘quantum simulators’ are now becoming a reality.

This *Nature Physics* Insight surveys the progress made so far. The series of articles review the state of the art for quantum simulators based on atomic quantum gases, ensembles of trapped ions, photonic systems and superconducting circuits. The list is by no means exhaustive; quantum simulations are being implemented in, or have been proposed for, a number of other systems — among them nuclear spins addressed using NMR methodology, and electron spins in quantum dots or in point defects.

The competition between the different platforms isn’t, however, a ‘winner takes all’ situation. Each platform has its own advantages and limitations, and different approaches often tackle complementary aspects of quantum simulation. What they have in common is their aim to solve problems that are computationally too demanding to be solved on classical computers, at least at the moment. Furthermore, the simultaneous development of several platforms for practical quantum simulation offers the intriguing prospect of verifying, once uncharted territory is reached, one simulator using another. In fact, implementing quantum simulations that are too complex for the most powerful classical computers should be already a short-term goal, say Ignacio Cirac and Peter Zoller in their Commentary, and the criteria they set out for a quantum simulator to fulfil might serve as guidelines towards reaching that aim.

We hope that these articles will provide a solid background and historical perspective, together with a broad survey of what has already been achieved. Most of all, we hope that the Insight conveys the excitement of a field that is still young, and inspires further reading — and research.

Andreas Trabesinger, Senior Editor

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