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A New Electromagnetism Can Be Simulated Through a Quantum Simulator

A quantum simulator is a variant of a quantum computer that allows us to outperform classical computers in the understanding of complex quantum systems.

There are two fundamental aspects that make these devices attractive for scientists. On the one hand, quantum simulators will play a leading role in clarifying some important, but yet unsolved, puzzles of theoretical physics. On the other hand, such deeper understanding of a given phenomenon will certainly give rise to useful technological applications.

One of the best quantum simulators consists of a gas of extremely cold atoms loaded in an artificial crystal made of light: an optical lattice. Experimental physicists have developed efficient techniques to control the quantum properties of this system, to such extent, that it serves as an ideal quantum simulator of different phenomena.

So far, efforts have been focused on condensed-matter systems, where many open and interesting problems remain to be solved.

In a recent work published in Physical Review Letters by a collaboration of international teams (Universidad Complutense de Madrid: A. Bermudez and M.A. Martin-Delgado; ICFO Barcelona: M. Lewenstein; Max-Planck Institute Garching: L. Mazza, M. Rizzi; Universite de Brussels: N. Goldman), this platform has also been shown to be a potential quantum simulator of high-energy physics.

The authors have proposed a clean and controllable setup where a variety of exotic, but still unobserved, phenomena arise. They describe how to build a quantum simulator of Axion Electrodynamics (high-energy physics), and 3D Topological Insulators (condensed matter). In particular, these results pave the way to the fabrication of an Axion, a long sought-after missing particle in the standard model of elementary particles. They show that their atomic setup constitutes an axion medium, where an underlying topological order gives rise to a non-vanishing axion field.

Besides, they show how the value of the axion can attain arbitrary values, and how its dynamics and space-dependence can be experimentally controlled. Accordingly, their optical-lattice simulator offers a unique possibility to observe diverse effects, such as the Wiiten effect, the Wormhole effect, or a fractionally charged capacitor, in atomic-physics laboratories.

This work has an interdisciplinary character, which brings together physicists specializing in lattice gauge theories, atomic molecular and optical physics, and condensed matter physics.