A novel tool to probe fundamental matter

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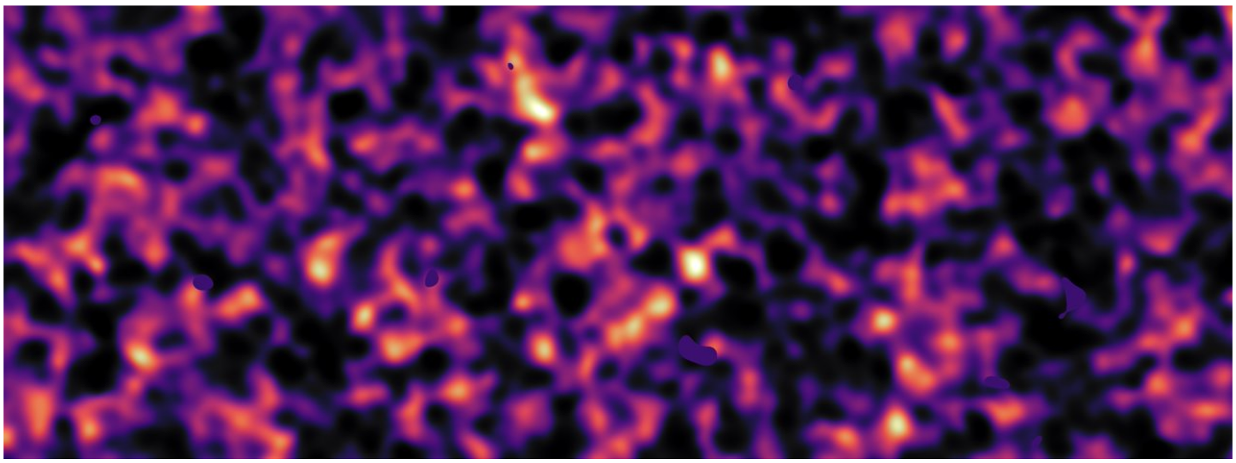

Dark matter map of KiDS survey region (region G12). Credit: KiDS survey

Identifying elementary constituents of matter including quarks, bosons and electrons, and the manner by which these particles interact with each other, constitutes one of the greatest challenges in modern physical sciences. Resolving this outstanding problem will not only deepen our understanding of the early days of the universe, but will also shed light on exotic states of matter, such as superconductors.

Besides gases, liquids and solids, matter can exist in other forms when it is subjected to extreme conditions. Such situations were encountered in the universe right after the Big Bang, and they can also be mimicked in the laboratory. And while a plethora of elementary particles were discovered in high-energy colliders, complex questions regarding their interactions and the existence of novel states of matter remain unanswered.

In collaboration with the experimental group of Immanuel Bloch, Monika Aidelsburger and Christian Schweizer (Munich), and theorists Eugene Demler and Fabian Grusdt (Harvard), Nathan Goldman and Luca Barbiero (Physics of Complex Systems and Statistical Mechanics, Science Faculty) have proposed and validated a novel experimental approach by which these rich phenomena can be studied.

Published in *Nature Physics*, their work reports on the experimental realization of a "lattice gauge theory," a theoretical model initially proposed by Kenneth Wilson, Nobel Prize in Physics recipient in 1982, to describe the interactions between elementary particles such as quarks and gluons. The authors demonstrate that their experimental setup, an ultracold gas of atoms manipulated by lasers, reproduces the characteristics of such a model. The challenge consisted of implementing well-defined interactions between matter particles and gauge bosons, which are the mediators of fundamental forces. In the cold-atom context, these types of particles are represented by different atomic states, which can be addressed in a very fine manner using lasers.

This novel experimental approach constitutes an important step for the quantum simulation of more sophisticated theories, which may eventually shed some light on open questions in high-energy and solid-state physics using table-top experiments.

More information: Floquet approach to $\mathbb{Z}2$ lattice gauge theories with ultracold atoms in optical lattices, *Nature Physics* (2019). DOI: 10.1038/s41567-019-0649-7 , nature.com/articles/s41567-019-0649-7

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