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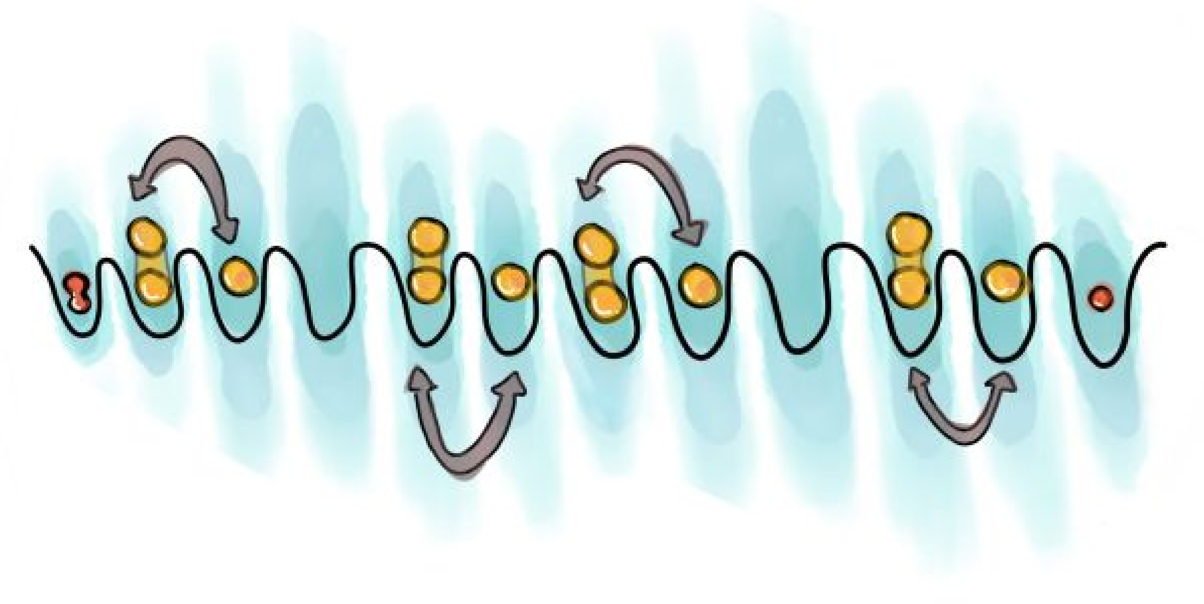

# Topological Quantum Critical Points in the Extended Bose Hubbard Model

## A recent study published in Physical Review Letters predicted the existence of a new state of matter: quantum critical points with topological properties occurring in the paradigmatic strongly-correlated extended Bose-Hubbard model

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Condensed matter physics deals with systems of many interacting particles which can be in different phases of matter. One of the main achievements of the last century was the development of the Ginzburg-Landau theory, which allows to classify distinctive phases by means of local order parameters. Nevertheless, in the last decades, a new class of states of matter escaping this paradigm has been discovered: the topological phases. One of the most revolutionary properties of such quantum regimes is that, while particles in the edges of the system can flow without friction, the bulk of the systems remains insulating. The further discovery of a great variety of unexpected properties has led to an intensive investigation of topological phases of matter in many areas of quantum physics ranging from solid state and quantum chemistry to high-energy physics and quantum computation.

The research on topological insulators reached its first peak in 1997, when Altland and Zirnbauern classified all the possible topological phases of non-interacting systems by means of symmetry arguments. Even though this classification shed light on many novel features of quantum matter, the picture is still far from being complete. The list of exotic topological phases that escape the current classification is only growing, with a special focus on the discovery of interaction-induced topology in strongly correlated systems.

The study of interaction-induced topological phases is particularly challenging due to the high level of complexity encoded in interacting systems, which nowadays needs to be tackled through quantum algorithms working on classical processors. Nevertheless, the advent of a new generation of quantum simulators made of particles at ultracold temperatures represents reliable a rout towards a complete understanding and control of topological phases in interacting systems.

In a recent article published in Physical Review Letters, ICFO researcher Joana Fraxanet, together with IQOQI researcher Daniel Gonzalez-Cuadra led by Prof. Maciej Lewenstein and Luca Barbiero from Politecnico di Torino, in collaboration with the experimental group of Prof. Tilman Pfau and Tim Langen from Universitat Stuttgart, reveal that interacting processes can lead to topological properties persisting at the specific points separating two distinct phases, thus leading to the existence of topological quantum critical points. In addition, the authors propose a realistic scheme based on magnetic dysprosium atoms whose long-range dipolar interaction enables the implementation of topological quantum critical points on a quantum simulator.

More specifically, the team of researchers reported the presence of two distinct topological quantum critical points with localized edge states and gapless bulk excitations. The results show that the topological critical points separate two phases, one topologically protected and the other topologically trivial, both characterized by a string correlation function which denotes a similar type of long-range ordering. In both cases, the long-range order persists also at the topological critical points and explains the presence of localized edge states protected by a finite charge gap. Finally, they introduce a super-resolution quantum gas microscopy scheme for dipolar dysprosium atoms for the experimental study of topological quantum critical points using cold atoms in optical lattices.

Figure caption: The Haldane insulator is a symmetry protected topological phase which is found in the extended Bose Hubbard model at filling one. The topology extends to the critical point separating the Haldane insulator from a charge density wave. ©ICFO/ J. Fraxanet