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Coherent dynamics and topological phases with ultracold atoms

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Ultracold atoms and ions have the potential to answer several long-standing questions about many-particle physics. The first part of this talk discusses coherent quantum dynamics in many-particle systems, focusing on the role of integrability and using the quantum Ising model recently created in ion trap experiments as an example. We discuss universal scaling near quantum phase transitions, including the emergence of a remarkable spectrum of massive particles near the quantum Ising critical point as predicted by Zamolodchikov years ago, and the role of disorder and "many-body localization." The second part of this talk discusses using the tunability of atoms in optical lattices to realize topological phases, including the recently discovered topological insulators in time-reversal invariant systems. Topological phases contain a type of order that is quite different from conventional symmetry breaking. The topological phases that have been experimentally confirmed to exist in condensed matter all have an energy gap in bulk but gapless edge or surface excitations. We review the origin of this behavior and discuss how ultracold atomic systems could bring new understanding to the study of topological phases.