

ALEJANDRO ZAMORA

Alejandro Zamora Zamora
Cargado: 10/11/2014



PhD Thesis Defense ALEJANDRO ZAMORA ?Quantum Gauge Theory Simulation with Ultracold Atoms?

ALEJANDRO ZAMORA

December 15, 2014

Monday December 15, 11:00. ICFO Auditorium

ALEJANDRO ZAMORA

Quantum Optics Theory

ICFO-The Institute of Photonic Sciences, SPAIN

The study of ultracold atoms constitutes one of the hottest areas of atomic, molecular, and optical physics and quantum optics. The experimental and theoretical achievements in the last three decades in the control and manipulation of quantum matter at macroscopic scales lead to the so called third quantum revolution. Concretely, the recent advances in the studies of ultracold gases in optical lattices are particularly impressive. The very precise control of

the diverse parameters of the ultracold gas samples in optical lattices provides a system that can be reshaped and adjusted to mimic the behaviour of other many-body systems: ultracold atomic gases in optical lattices act as genuine quantum simulators. The understanding of gauge theories is essential for the description of the fundamental interactions of our physical world. In particular, gauge theories describe one of the most important classes of systems which can be addressed with quantum simulators. The main objective of the thesis is to study the implementation of quantum simulators for gauge theories with ultracold atomic gases in optical lattices.

First, we analyse a system composed of a non-interacting ultracold gas in a 2D lattice under the action of an exotic and external gauge field related to the Heisenberg-Weyl gauge group. We describe a novel method to simulate the gauge degree of freedom, which consists of mapping the gauge coordinate to a real and perpendicular direction with respect to the 2D space of positions. Thus, the system turns out to be a 3D insulator with a non-trivial topology, specifically, a quantum Hall insulator.

Next, we study an analog quantum simulation of dynamical gauge fields by considering spin-5/2 alkaline-earth atoms in a 2D honeycomb lattice. In the strongly repulsive regime with one particle per site, the ground state is a chiral spin liquid state with broken time reversal symmetry. The spin fluctuations around this configuration are given in terms of an emergent U(1) gauge theory with a Chern-Simons topological term. We also address the stability of the three lowest lying states, showing a common critical temperature. We consider experimentally measurable signatures of the mean field states, which can also be key insights for revealing the gauge structure.

Then, we introduce the notion of constructive approach for the lattice gauge theories, which leads to a family of gauge theories, the gauge magnets. This family corresponds to quantum link models for the U(1) gauge theory, which consider a truncated dimensional representation of the gauge group. First of all, we (re)discover the phase diagram of the gauge magnet in 2+1 D. Then, we propose a realistic implementation of a digital quantum simulation of the U(1) gauge magnet by using Rydberg atoms, considering that the amount of resources needed for the simulation of link models is drastically reduced as the local Hilbert space shrinks from infinity to 2D (qubit).

Finally, motivated by the advances in the simulation of open quantum systems, we turn to consider some aspects concerning the dynamics of correlated quantum many body systems. Specifically we study the time evolution of a quench protocol that conserves the entanglement spectrum of a bipartition. We consider the splitting of a critical Ising chain in two independent chains, and compare it with the case of joining two chains, which does not conserve the entanglement spectrum. We show that both quenches are both locally and globally distinguishable. Our results suggest that this conservation plays a fundamental role in both the out-of-equilibrium dynamics and the subsequent equilibration mechanism.

Monday December 15, 11:00. ICFO Auditorium

Thesis Advisor: Prof. Dr. Maciej Lewenstein

Thesis Co-advisor: Dr. Gergely Szirmai

