From cavity QED to quantum simulations with Rydberg atoms

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Rydberg atoms and microwave photons stored in a high Q cavity constitutes a nearly ideal system for realizing a "photon box" in the spirit of gedanken experiments introduced by Einstein and Bohr for emphasizing the unbelievable strangeness of quantum theory. In the first part of the course, we will show how the experiment illustrates fundamental features of quantum measurement theory, like state projection and decoherence. On the basis on a quantum non-demolition (QND) photon counting method, we will present methods for reconstructing the quantum state stored in the cavity and to follow its quantum trajectory. Application to Schrödinger cat state preparation, to quantum feedback sate stabilization and to the past quantum state reconstruction methods will be discussed.

The second part of the lecture, will present new perspectives for building a quantum simulator of a 1D XXZ spin Hamiltonian. The simulator is based on the strong dipole-dipole van der Walls interaction between Rydberg atoms trapped in a 1D chain. We will show that a single circular Rydberg atom can be trapped over time scales larger than a minute. We will discuss the potential of this system for quantum simulations involving several tenths of atoms for exploring the phase diagram of the XXZ Hamiltonian, and the physics of quench, transport and localization.