Dissipative phase transitions in coupled cavity arrays: correlations and complexity

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Arrays of coupled QED-cavities offer a unique playground for the investigation of open many-body systems in nonequilibrium conditions and they are particularly appealing from the condensed matter physics perspective since they allow the quantum simulation of archetypal (interacting) lattice models [1]. The coupling between different unit cells can give rise to a plethora of cooperative phenomena determined by the complex interplay between Hamiltonian dynamics, dissipation, and external driving. In the work I will present [2], we have explored the physics of a lattice of coupled resonators with giant optical nonlinearities where optical gain is provided by incoherently pumped two-level systems. We predict a dissipative phase transition, associate with the spontaneous breaking of the $U(1)$ symmetry, from a localized *Mott-like* phase of photons to a coherent delocalized phase, which is akin to a coherent laser of strongly correlated photons.

Next, I will discuss some recent development in numerical approaches to tackle the emerging complexity in open many-body systems. In particular I will talk about the generalization to open systems of cluster methods as Cluster Mean-Field [3] and Linked Cluster Expansions [4], highlighting the role of short-range correlations in driven-dissipative systems.

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