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The road towards strongly correlated many-body cavity QED

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Cavity quantum-electrodynamics (QED) is the science of strong light-matter interactions between a driven, ultracold quantum gas and the photon modes of an optical cavity. Over the past 15 years, these platforms have played a pivotal role in our ability to create and explore phases of matter that transcend conventional thermodynamics, forging the field of driven-open quantum simulators.

In this colloquium, I will illustrate our progresses to upgrade the theory of many- body cavity QED towards an unexplored frontier, heralded by the rise of a new generation of quantum technologies. Similarly to emergent phenomena in solid state physics, and at variance with previous quantum optics experiments, these new platforms hold the promise to synthesize stable correlated quantum matter under strongly dissipative conditions. This hints at the advent of a research domain where quantum optics merges with condensed matter, under the perspective to deliver uncharted applications in quantum information science.

My talk is built around two concrete examples of this emergent research area: (i) the analysis of an experiment where quantum fluctuations are tunable and, when strong enough, capable to mold a new class of quantum spin glasses, and (ii) the breakdown of the paradigm of correlations spreading in non-equilibrium systems, employing programmable decoherence in many-body cavity QED.