Quantum many-body systems driven out of equilibrium host a plethora of interesting phenomena, ranging from generation of quantum entanglement to novel dynamical phases of matter, which are useful towards developing next-generation quantum technologies, yet remain poorly understood. Recent experimental progresses in preparing and probing ensembles of ultracold atoms have opened up unique opportunities for investigating complex quantum many-body phenomena in the non-equilibrium regime. In this talk, I will report on recent developments both in theory and experiment towards understanding the quantum dynamics in interacting atomic ensembles, focusing on two platforms, magnetic atomic dipoles, and atoms coupled via photon mediated interactions. Both of them feature strong and long-range atomic interactions, which pose challenges for theoretical treatment. I will present a new theoretical approach for tackling such challenges and demonstrate its application for extracting quantum features from experiments. In particular, I will show how the interplay between long-range interactions and quantum fluctuations can result in rich and useful many-body behaviors. I will further discuss prospects offered by these studies for pushing the frontiers of fundamental physics and to generate quantum correlated many-body states for applications in both quantum computation and metrology.