Superradiant Dicke transition with two-level atoms in free space

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The theoretical description of collective spontaneous emission by an ensemble of quantum emitters is a remarkably challenging many-body problem, with broad impact. In this talk, I will describe experiments aimed at studying textbook collective dissipation problems, with cold atoms.

We study dense ensembles of two-level atoms resonantly driven on their transition. Measuring the collective emission of radiation during Rabi osillcations, we experimentally demonstrate the coupling of the atomic clouds to a directional emission mode, where superradiant emission takes place. By observing both the atomic excited state fraction and photo-emission in the superradiant mode, we are able to demonstrate the spontaneous emergence of two-atom correlations in the ensemble. We also drive the atoms directly in the superradiant mode and observe a transition from an undriven regime where the drive field is screened by a collective dipole and a superradiant phase akin to that observed in superradiant lasers in the bad cavity regime, established here in the absence of a cavity. This transition was predicted early in the driven Dicke model, and we show that our experimental data is remarkably reproduced by the driven Dicke model, with an effective atom number modified by the extended geometry of our clouds, as is known for Dicke superradiance in extended samples.