Quantum crystals of photons and atoms

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In this talk I will discuss several examples of selforganization of atoms inside a single-mode resonator. When a laser transversally pumps the atom, photon scattering into the resonator depends on the atoms density distribution within the cavity, and in turn determines the strength of the mechanical forces of light on the atoms, hence the atomic density. The dynamics is thus nonlinear and can lead to ordered atomic structures when the laser intensity exceeds a threshold determined, amongst other, by the rate of cavity losses. I will first discuss the dynamics of selforganization in the semiclassical regime, in which the atomic motion is cooled by the photon scattering processes which pump the cavity. I will then consider the quantum regime, where the atoms are ultracold bosons. The atoms are confined by an external optical lattice, whose period is incommensurate with the cavity mode wave length, and are driven by a transverse laser, which is resonant with the cavity mode. While for pointlike atoms photon scattering into the cavity is suppressed, for sufficiently strong lasers quantum fluctuations can support the build-up of an intracavity field, which in turn amplifies quantum fluctuations. In this parameter regime the atoms form clusters which are phase locked, thereby maximizing the intracavity photon number. I will argue that this system constitutes a novel setting where quantum fluctuations give rise to effects usually associated with disorder.