Kinetic theory of cavity cooling and self-organisation of a cold gas

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We study spatial self-organisation and dynamical phase-space compression of a dilute cold gas of laser-illuminated polarisable particles in an optical resonator. Deriving a non-linear Fokker-Planck equation for the particles' phase-space density allows us to treat arbitrarily large ensembles in the far-detuning limit and explicitly calculate friction forces, momentum diffusion and steady-state temperatures. In addition, we calculate the self-organisation threshold in a self-consistent analytic form. For a homogeneous ensemble below threshold the cooling rate for fixed laser power is largely independent of the particle number. Cooling leads to a *q*-Gaussian velocity distribution with a steady-state temperature determined by the cavity linewidth. Numerical simulations using large ensembles of particles confirm the analytical threshold condition for the appearance of an ordered state, where the particles are trapped in a periodic pattern and can be cooled to temperatures close to a single vibrational excitation.