Dissipative Phase Transition in a Driven Dicke Model

1 Model

We consider collective spin-S system which is coupled to a dissipative cavity mode and driven by an external field. The master equation for this system is

$$\dot{\rho} = -i[H,\rho] + \kappa(2a\rho a^\dagger - a^\dagger a\rho - \rho a^\dagger a) + \frac{\Gamma}{N}(2S_-\rho S_+ - S_+S_-\rho - \rho S_+S_-), \tag{1}$$

where

$$H = \Omega S_x + \frac{g}{\sqrt{N}}(S_-a^\dagger + S_+a). \tag{2}$$

Here $S_\pm = S_x \pm iS_y$ and $S_k = 1/2\sum_i \sigma_k^i$ are the usual collective spin operators. When the damping rate κ of the cavity is very large, the cavity mode can be adiabatically eliminated, and we obtain a reduce model for a driven spin with a damping rate of

$$\Gamma \qquad \rightarrow \qquad \tilde{\Gamma} = \Gamma + \frac{g^2}{\kappa}. \tag{3}$$

It is know that for $N \to \infty$ this model has a phase transition at a critical driving strength $\Omega = \tilde{\Gamma}$, but for many decades physicists were wondering what actually happens for finite N and when the cavity cannot be adiabatically eliminated.

2 Example implementation with MATLAB

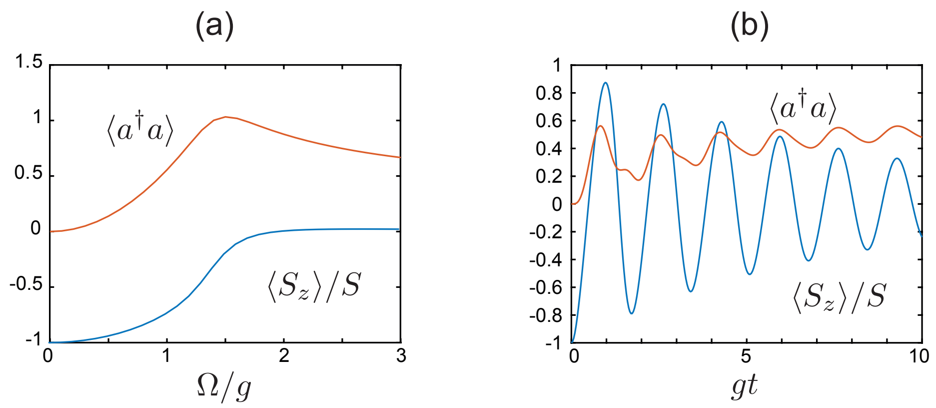

Figure 1: (a) Steady state and (b) time evolution with $\Omega/g = 5$. The other parameters are $N = 20$, photon cutoff $n_{\max} = 5$, $\kappa/g = 2$, $\Gamma/g = 0.5$