Controllability and optimal control of spins coupled to a dissipative cavity

Quentin Ansel¹, Dominique Sugny², and Bruno Bellomo¹

¹Institut UTINAM, CNRS UMR 6213, Université Bourgogne Franche-Comté, Observatoire des Sciences de l'Univers THETA, 41 bis avenue de l'Observatoire, F-25010 Besançon, France ²Laboratoire Interdisciplinaire Carnot de Bourgogne, CNRS UMR 6303,

Université Bourgogne Franche-Comté, BP 47870, F-21078 Dijon, France

We investigate theoretically the control of spin systems coupled to their environment. For that purpose, we consider two similar models with different levels of complexity, which can be used to describe one or several spins in interaction with a cavity whose degrees of freedom are quantized [1, 2]. Control tasks are performed by means of collective driving: coherent and squeezing light fields [2–4] in the case of several spins (model 1) or modulation of the spin energy transition in the case of a single spin under the restriction of a single quantum excitation at disposal in the system (model 2) [5]. A sketch of the two models is given in Fig. 1.



Fig. 1: sketch of the two models.

We first analyze the controllability of the systems with Lie algebra computations and numerical simulations. This allows us to characterize precisely the set of possible transformations. The role of squeezing light fields and non-Markovian dynamical effects are discussed. Then, using optimal control theory [6] we investigate several control tasks, such as the generation of non-classical states in the first model[7], or the selectivity of independent spins in the second model [8]. Control mechanisms are highlighted and the physical limits of the processes are discussed. In particular, the detrimental effect of the cavity damping is analyzed [7].

- N. Samkharadze *et al.*, "Strong spin-photon coupling in silicon", Science **359**, 6380 (2018).
- [2] A. Bienfait *et al.*, "Magnetic Resonance with Squeezed Microwaves", Phys. Rev. X 7,041011 (2017).
- [3] C. W. Gardiner and A. S. Parkins, "Driving atoms with light of arbitrary statistics", Phys. Rev. A 50, 1792 (1994).
- [4] S. Probst *et al.*, "Shaped pulses for transient compensation in quantum-limited electron spin resonance spectroscopy", J. of Mag. Res. **303**, 42 (2019).
- [5] M. Janowicz, "Non-Markovian decay of an atom coupled to a reservoir: Modification by frequency modulation", Phys. Rev. A 61, 025802 (2000).
- [6] S. J. Glaser *et al.*, "Training Schrödinger's cat: quantum optimal control", Eur. Phys. J. D 69, 279 (2015).
- [7] Q. Ansel, D. Sugny, and B. Bellomo, in preparation.
- [8] Q. Ansel, J. Fischer, D. Sugny, and B. Bellomo, in preparation.