# Stochastic Resonance of Spinor Condensates in Optical Cavity

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**Abstract**— Stochastic resonance (SR) is a phenomenon in which adding random noise to a system enhances the detection or transmission of a weak signal. It occurs when the noise interacts with the system's nonlinearity, thus improving the signal-to-noise ratio and increasing the sensitivity. Although parametric resonances in an atomic spinor Bose-Einstein condensate have been investigated, the question of whether one can observe stochastic resonance in such a system persists. Recently, the research regarding SR has expanded into the quantum realm, such as J-C model [1], Dick model [2] and cavity optomechanical system [3]. Specifically, the investigation of SR in quantum many-body systems facilitates the realization of noise-induced beneficial effects and deepens our understanding of the interplay between many-body interactions and quantum fluctuations.

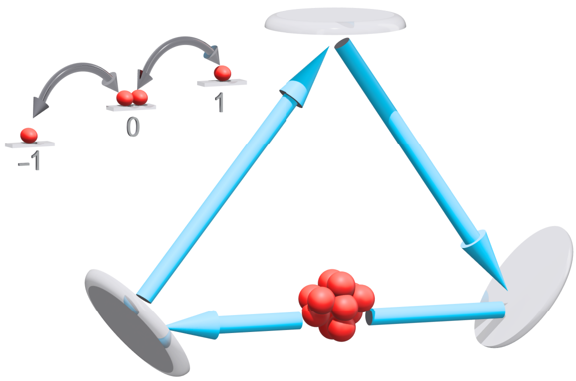


Figure 1: $F = 1$ spinor condensate trapped in a ring cavity, externally driven by time-varying $\epsilon_p(t)$ and decaying at rate $\kappa$. The $\pi$-polarized cavity field interacts dispersively, inducing a quadratic Zeeman shift. Spin-dependent collisions cause population redistribution among spin components.

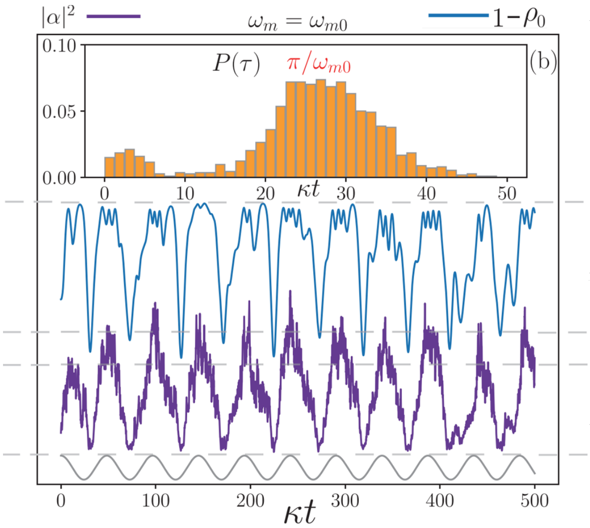


Figure 2: Under the mean-field approximation, the temporal changes in the photon number and the spin-0 population when the driving frequency matching the optimal frequency. The figure demonstrates a clear manifestation of stochastic resonance phenomenon.

In this study we propose a scheme for generating stochastic resonance in a cavity-spinor Bose-Einstein condensate coupling system, as shown in Fig. 1. We demonstrate stochastic resonance through numerical calculations using the mean-field theory and truncated Wigner approximation methods. Under both methods, we obtained the parameter conditions that result in stochastic resonance occurrence and verified the generation of stochastic resonance. Furthermore, the characteristics of the system's response to noise and periodic signals are studied in detail. Partial results are shown in Fig. 2. We anticipate that the proposed scheme can be readily implemented experimentally with recent advances in coupling a ring cavity with cold atoms [4] and BECs [5]. This study unravels a new scheme for observing stochastic resonance via linking atomic many-body physics with cavity quantum electrodynamics. The main results of this work are accepted by *SCIENCE CHINA Physics, Mechanics & Astronomy* [6].

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