Robust Tripartite Entanglement Generation via Correlated Noise in Spin Qubits

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Qubits inevitably interact with noisy environments, causing errors that require quantum error correction (QEC) While
QEC can mitigate local uncorrelated noise, spatially correlated noise remains particularly challenging for existing schemes. Such pairwise correlated noise has been observed in semiconductor spin qubits, Recent studies in spin qubit systems also demonstrate the dissipative generation of Bell states via spatially correlated noise. However, this long-lived bipartite entanglement is highly sensitive to inversion symmetry breaking in the environment Beyond bipartite entanglement, scalable quantum technologies often require multipartite entanglement nonclassical correlations shared among multiple qubits
This raises an important question: can pairwise correlated noise be leveraged to generate genuine multipartite entanglement? Furthermore, since the multipartite entanglement is of a fundamentally different nature than the bipartite entanglement in a two-qubit system. Beyond the fundamental significance, understanding how multipartite entanglement emerges and persists in realistic noisy environments is essential for the development of scalable and fault-tolerant quantum technologies.

We investigate the generation of genuine tripartite entanglement in a triangular spin-qubit system due to spatially correlated noise. In particular, we demonstrate how the formation of a highly entangled dark state—a W state—enables robust, long-lived tripartite entanglement. Surprisingly, we find that environmentally induced coherent coupling does not play a crucial role in sustaining this entanglement. This contrasts sharply with the two-qubit case, where the induced coupling significantly influences the entanglement dynamics. Furthermore, we explore two promising approaches to enhance the tripartite entanglement by steering the system towards the dark state: post-selection and coherent driving. Our findings offer a robust method for generating high-fidelity tripartite entangled states with potential applications in quantum computation.

References

[1] S. Driessen, J. Zou, E. Thingstad, J. Klinovaja, and D. Loss, arXiv:2506.20466 (2025).

Figures

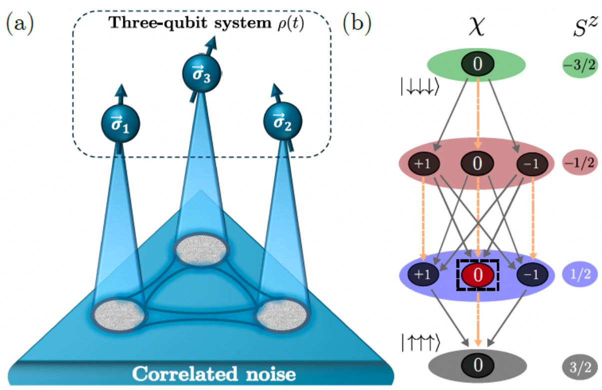

Figure 1: (a) A system of three spin qubits is arranged in an equilateral triangle and coupled to a noisy environment. (b) The states of the three-qubit system [spheres in (b)] can be labeled by the eigenvalues of the chirality operator. Noise induces transitions (arrows) between the eigenstates, while correlated spatial noise introduces an imbalance in the transition amplitudes. When the non-local dissipation is strong, one type of transition can be suppressed (orange dashed arrows), and this allows the formation of a dark state (dashed box).