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Numerical analysis of the angular-time correlation functions for the S = 1 Heisenberg chain

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The ground states of low-dimensional quantum many-body systems exhibit theoretically fascinating behaviors, such as quantum spin liquids and symmetry-protected topological orders. In their theoretical analysis, entanglement entropy(EE) and spectrum(ES) often play an essential role as a quantitative indicator of the quantum many-body entanglement. Meanwhile, verifying quantum many-body entanglement in realistic quantum spin systems is still a challenging problem because EE and ES are not directly observable quantities. In this work, we discuss the angular-time evolution approach for spin operators to detect the ES in the ground state of the S=1 Heisenberg spin chain, which is well-known as a Haldane state. Such a protocol for the ES utilizing the angular-time correlation function was initially introduced for the XXZ chain based on the theoretical analogy between the Unruh effect in quantum gravity and the quantum entanglement structure for its bipartitioned ground state[1]. Moreover, recently, we successfully applied the protocol to the Affleck-Kennedy-Lieb-Tasaki (AKLT) chain, which has symmetry-protected topological entanglement associated with Z2 x Z2 symmetry, and found that the angular-time evolution can be interpreted as a real-time evolution of the edge state induced by a uniform magnetic field in the system part with the use of a gauge transformation for the matrix product state[2]. However, the AKLT chain is a rather mathematical model with no experimental counterpart. Using the density matrix renormalization group, we thus analyze the angular-time evolution for the ground state of the S=1 Heisenberg chain and then discuss whether we can correctly capture the ES in a realistic experimental situation.

[1] K. Okunishi and K. Seki, J.Phys. Soc. Jpn. 88, 114002 (2019)
[2] K. Nakajima and K. Okunishi, Phys. Rev. B 106, 134304 (2022)

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