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Eigenstate entanglement in integrable collective spin models

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The characterization of integrability and chaos in quantum mechanics is a long-standing open problem. Entanglement is a strong candidate for this characterization but exactly how remains debatable. The average entanglement entropy (EE) of the energy eigenstates in non-vanishing partitions has been recently proposed as a diagnostic of integrability in quantum many-body systems. For it to be a faithful characterization of quantum integrability, it should distinguish quantum systems with a well-defined classical limit in the same way as the unequivocal classical integrability criteria. We examine the proposed diagnostic in the class of collective spin models characterized by permutation symmetry in the spins. The well-known Lipkin-Meshov-Glick (LMG) model is a paradigmatic integrable system in this class with a well-defined classical limit. Thus, this model is an excellent testbed for examining quantum integrability diagnostics. First, we calculate analytically the average EE of the Dicke basis in any non-vanishing bipartition, and show that in the thermodynamic limit, it converges to 1/2 of the maximal EE in the corresponding bipartition. Using finite-size scaling, we numerically demonstrate that the aforementioned average EE in the thermodynamic limit is universal for all parameter values of the LMG model. Our analysis illustrates how the value of the average EE in the thermodynamic limit may be a robust criteria for identifying integrability.

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