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Quantum Complexity in Neutrino Flavour Oscillation

Neutrino flavour oscillation offers a valuable avenue to probe physics beyond the Standard Model. Despite significant progress, key questions remain unresolved particularly the neutrino mass hierarchy and the constraints on parameters governing flavour oscillation, such as the mixing angle theta;₂₃ and the Charge-Parity (CP) violating phase delta;_{CP}. In this study, we aim to explore these questions by applying a concept from Quantum Information Theory: quantum complexity.Quantum complexity quantifies the "difficulty"of constructing a given quantum state from a reference state using a set of universal unitary operations (quantum gates). Specifically, we will use Nielsen's geometric approach to complexity, which focuses on the geometry of the space of unitary operators. In this operator approach, complexity is defined as the minimal geodesic distance from the identity operator to a target unitary. In our case, the target unitary is the time evolution operator governing neutrino oscillation. We first compute the complexity of two-flavour neutrino oscillation, and then extend our analysis to the three-flavour case. We investigate how the oscillation parameters influence the complexity and compare our findings with conventional probabilistic approaches.

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