

Quantum geometry effects in quantum field theory: Hamiltonian constraint generates gravity-matter entanglement in spherically symmetric loop quantum gravity

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In this work, we address a foundational challenge in quantum field theory on curved spacetime by developing a consistent framework in spherically symmetric loop quantum gravity. We introduce a methodology for defining meaningful superpositions of quantum geometry and matter states near the semiclassical apparent horizon. This is achieved by identifying a restricted subspace of the gravitational phase space, which ensures unitary equivalence among Fock representations of a scalar field across different quantum geometries. Within the resulting well-defined state space, we derive weak solutions to the quantum Hamiltonian constraint of general relativity near the semiclassical apparent horizon. Furthermore, we generalize the Hartle-Hawking vacuum state to this quantum geometric framework. The resulting state exhibits the inherent entanglement between geometry and matter, which arises from the quantum Hamiltonian constraint of general relativity. This work establishes a principled framework for studying geometry-matter entanglement and offers new insights into the quantum foundations of the black hole information paradox.

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