Contribution ID : **129** Type : **not specified**

Reflected entropy for a two-sided black hole model

Tuesday, 3 December 2024 09:00 (40)

The black hole information paradox has been an important problem in quantum gravity. In the study of evaporating black hole, it has been proposed that the holographic map between the semi-classical effective description in bulk and the fundamental description in boundary cannot be isometric. In this work, we would like to study the reflected entropy in an evaporating black hole model through non-isometric holographic map. We assume that the evaporating is slowly enough that it makes sense to ascribe a slowly varying temperature to the Hawking radiation. We then introduce a two-sided black hole model to canonically purify the semi-classical state. The holographic map to the fundamental description is non-isometric and defined by a Haar random unitary matrix. We show that the entanglement entropy of the radiation in the model matches the result read from the quantum extremal surface formula and agrees with the Page curve. Furthermore, we study the reflected entropies between different regions, including the one between the black holes on different sides, the one between the radiations distributed symmetrically but disconnectedly, and the one between the black hole and the radiation on single side. Our results are consistent with the existing ones based on the effective descriptions.

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Session Classification : Day4 Main venue