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Entanglement island, miracle operators and the firewall

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In this work, we obtain some general results on information retrieval from the black hole interior, based on the recent progress on quantum extremal surface formula and entanglement island. We study an AdS black hole coupled to a bath with generic dynamics, and ask whether it is possible to retrieve information about a small perturbation in the interior from the bath system. We derive a state reconstruction formula based on one norm. However, we show that a contradiction arises if we apply this result to a special situation when the bath dynamics includes a unitary operation that carries a particular measurement to a region A and send the result to another region W. Physically, the contradiction arises between transferability of classical information during the measurement, and non-transferability of quantum information which determines the entanglement island. We propose that the resolution of the contradiction is to realize that the state reconstruction formula does not apply to the special situation involving interior-information-retrieving measurements. This implies that the assumption of smooth replica AdS geometry with boundary condition set by the flat space bath has to break down when the particular measurement operator is applied to the bath. Using replica trick, we introduce an explicitly construction of such operator, which we name as miracle operators". From this construction we see that the smooth replica geometry assumption breaks down because we have to introduce extra replica wormholes connecting with the simulated blackholes" introduced by the miracle operator. We study the implication of miracle operators in understanding the firewall paradox.

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