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Properties of dynamical regular black holes in semiclassical gravity

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Regular black holes have become a popular alternative to the singular mathematical black holes predicted by general relativity as they circumvent mathematical pathologies associated with the singularity while preserving crucial black hole features such as the trapping of light. Based on the assumption that semiclassical gravity is valid in the vicinity of their apparent horizons, we examine the behavior of the null energy condition and study the trajectories of particles entering and exiting the trapped spacetime region throughout its evolution. We find that the null energy condition is always violated in the vicinity of the outer horizon while being satisfied in the vicinity of the inner horizon, which implies that the trapped spacetime region (as determined from the behavior of null geodesic congruences) is effectively separated into an NEC-violating and an NEC-non-violating domain. We show that quantum effects are more dominant close to the outer apparent horizon and become more pronounced towards the final stages of the evaporation process. In addition, we demonstrate that there is a unique way for particles to escape the trapped region on an ingoing geodesic, thus offering a natural resolution to the information loss paradox. Lastly, we highlight the physical implications of these results and outline how the parameters of various theoretical models are constrained by current and future observational data (e.g. through light rings).

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