Contribution ID: **76** Type: **not specified**

Boulware Vacuum vs. Regularity: Vacuum State on the Horizonless Regular Spacetime

Thursday, 10 July 2025 18:00 (20 minutes)

When quantum fields live in curved spacetime, their behavior is highly sensitive to the choice of vacuum, which reflects the global structure of the background spacetime. Furthermore, their renormalized stress-energy tensor (RSET) requires the introduction of a local higher-order curvature effect, which induces the trace anomaly. These facts highlight that both the global and local properties of spacetime critically influence the quantum fields and their RSET.

In this work, we examine the vacuum state and its corresponding renormalized stress-energy tensor (RSET) in static horizonless regular spacetime in both two and four dimensions. Using the local field formulation of the anomaly-induced effective action, we show that the regularities of the spacetime and the RSET dictate the appropriate vacuum state. Furthermore, through a case study under the horizonless Bardeen-type spacetime, we demonstrate that the preferred vacuum state is not the Boulware vacuum in the black hole spacetime case, but a nontrivial one with a different RSET profile.

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Session Classification: Parallel 1