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Aspects of transitivity in quantum field theory and its possible consequences

Testing transitivity in quantum field theory is a fundamental aspect of understanding the consistency of the theory and its predictions. In our paper, we considered a vacuum state of the massless scalar field in Minkowski spacetime and two Rindler wedges, Rindler-1 and Rindler-2, separated by a distance. From a set-theoretic view, this setup assumes the picture where the Minkowski spacetime with the scalar field defined on it is a universal quantum field set, and Rindler-1 and Rindler-2 are subsets or subsystems. Note here that Rindler-2 is also a subset of Rindler-1.

To investigate the transitivity, we have calculated the reduced state of the field in Rindler-2 in two independent ways. The first approach is straightforward: We took the vacuum state in Minkowski and found the reduced state in Rindler-2 by tracing-out the degrees of freedom of the left wedge, giving a Planckian spectrum. Similarly, in the second case, we first evaluated the reduced state in Rindler-1 from the vacuum of Minkowski, which yielded a thermal density matrix, and then the reduced density matrix in Rindler-2 from Rindler-1. We found that these independent paths of calculations do not yield the same reduced state in Rindler-2.

This variation in reduced state calculations indicates that there are quantum field theoretic systems in which the reduced quantum state of a subsystem can be path-dependent and, hence, not unique. Therefore, transitivity is violated, but it is still unclear whether this is a desirable property for a quantum field theory or a flaw in our current formulation of the quantum field theory.

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