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Operator Ordering Ambiguity in Observables of Quantum Cosmology

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We discuss the status of observables and operator ordering ambiguities in the quantum cosmology model with Brown Kuchař dust as the matter field. In order to study the dynamics of the FRW universe, Hubble parameter and Ricci scalar are expressed as a function of phase space variables. As these functions exhibit operator ordering ambiguity, several Hermitian extensions corresponding to these observables can be written. For the unitarily evolving semiclassical wave packet constructed in Kiefer et al. [Phys.Rev.D 99 (2019) 12, 126010], we computed the expectation value of these observables, which shows that very early in collapsing branch and very late in expanding branch, the expectation values of the Hubble parameter and Ricci scalar matches the classically obtained results irrespective of the operator ordering chosen. The expectation value of Hubble parameter is same for all operator orderings. The expectation value of Hubble parameter vanishes, and Ricci scalar attains an extremum at the point of classical singularity for all orderings, showing a robust bounce. The magnitude of this extrema is sensitive to the operator ordering chosen. For Weyl orderings, the expectation value of Ricci scalar becomes negative for certain parameter values. We have computed the expectation value of other curvature invariants as well, which follows the trend.

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