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## Expansion-collapse duality between Einstein and Jordan frames: Implications at quantum level

The Jordan and Einstein frame representations of scalar-tensor theories of gravity are mathematically equivalent; however, the cosmological evolutions therein can be drastically different. An interesting example is an expansion-collapse duality – a continually expanding Einstein frame universe can have a dual Jordan frame description that is always contracting. The scenario eventually runs into an apparent paradox. When a collapsing universe approaches singularity, the classical description of the spacetime becomes inadequate. The contracting Jordan frame universe is expected to develop quantum characteristics when its scale factor becomes sufficiently small. However, at the same time, the corresponding Einstein frame universe is expected to behave classically due to the arbitrarily large size it has grown to. In this case, the conformal map appears to be providing a duality between a quantum effect-dominated universe and a universe behaving classically. We investigate the status of the conformal map at the quantum level in such a scenario, focusing on addressing this paradox. The Einstein and Jordan frame universes are quantized individually using the Wheeler-DeWitt prescription. We show that the classical conformal map holds at the quantum level when compared through the expectation values of the scale factor operators in the two frames. The relative quantum fluctuation in the scale factor is found to be conformally invariant, and it increases in both the past and future directions according to the internal clock. Expectedly, the quantum fluctuations in the collapsing Jordan frame keep on increasing as it shrinks towards singularity. More surprisingly, the quantum fluctuations in the expanding Einstein frame keep on increasing as well, even as its classical scale factor becomes larger. Despite having drastically different cosmological evolutions, the rise in quantum characteristics in a collapsing frame implies the same in its expanding counterpart, thereby resolving the apparent paradox.

Based on "Einstein and Jordan frame correspondence in quantum cosmology:

expansion-collapse duality", Mukherjee and Sahota. Eur.Phys.J.C 83 (2023) 9, 803 (https://doi.org/10.1140/epjc/s10052-023-11934-9)

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