Contribution ID: **29** Type: **not specified**

Numerical study of quantum cosmology by the generalized Lefschetz thimble method

Friday, 9 December 2022 15:00 (20 minutes)

Quantum cosmology is established as a way to understand the beginning of universe. Picard-Lefschetz theory has raised recent interest on the "tunneling from nothing"proposal by Vilenkin and the "no boundary" proposal by Hartle-Hawking. The two proposals can be closely related through analysis on saddle points and boundary conditions. In this work, we demonstrate a first principle calculation on the mini-superspace model. We overcome the sign problem arising from the Lorentzian path integral formulation with generalized Lefschetz thimble method. At the initial time, we also perform calculations using the Robin boundary condition, which interpolates the Dirichlet and Neumann boundary conditions. The Stoke's theorem from Vilenkin to Hartle-Hawking can be shown at the critical value of interpolating factor in Robin boundary condition.

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Session Classification: Parallel session A