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Infrared signature of quantum bounce in collapsing geometry

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We study the mode decomposition of the unitarily evolving wave packet constructed for the quantum model of spherically symmetric dust collapsing in marginally bound Lemaître-Tolman-Bondi (LTB) model. We consider the model developed by Kiefer et al. [Phys.Rev.D 99 (2019) 12, 126010], where black hole singularity is replaced by a bounce from collapsing phase to expanding phase in the quantum dynamics of the dust cloud. We identify the observable depicting mode decomposition and using the freedom of operator ordering ambiguity wrote Hermitian extension of this operator alongside the Hermitian Hamiltonian. After identifying incoming and outgoing modes with this operator's eigenstates, we estimate their contributions. True to a quantum description, the expanding and contracting branches do not entirely comprise of outgoing and incoming radiation. For large wavenumber, the contribution of incoming and outgoing radiation is equal and very small. However, the infrared sector of this process shows salient features. Near-infrared modes are very sensitive to the dynamics of the dust cloud. Near the epoch of classical singularity, there is a significant contribution of incoming/outgoing modes of small wavenumber in the expanding/collapsing phase of the dust cloud. This contribution keeps on decreasing as one moves away from the singularity. Moreover for small wavenumber, the collapsing branch largely comprises of incoming modes, and the expanding branch comprises of outgoing modes. If one focuses on the infrared sector, the information of the bounce is carried over to the infrared modes, much before the information of the bounce comes about to any observer. A flip from largely incoming to largely outgoing radiation, as the evolution progressed from collapsing to expanding phase, is observed in the infrared regime. The information of the short scale physics is carried over to the longest wavelength in this quantum gravity model.

Author: SAHOTA, Harkirat Singh (IISER Mohali)

Co-author: Dr LOCHAN, Kinjalk (IISER Mohali)

Presenter: SAHOTA, Harkirat Singh (IISER Mohali)

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