14:30-, Thu 19th-February-2026
KPSI, Kyoto, JAPAN
The 116-th KPSI Seminar, QST

Quantum Universe Simulator using Quantum Hall Systems with an Expanding Edge

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Abstract

The edge excitations appearing in quantum Hall systems form a topologically robust state, whose low-energy dynamics are described by an effective theory of a massless chiral scalar field. When the edge is dynamically deformed, this scalar field obeys the same equation as the wave (Klein-Gordon) equation in a (1+1)-dimensional expanding universe [1]. This correspondence enables laboratory-based investigations of quantum phenomena associated with scalar fields in curved spacetime.

In this talk, motivated by an ongoing experimental setup in the experimental group at Tohoku University, we theoretically analyze a situation in which the edge region expands in a manner analogous to a de Sitter universe [2,3]. We discuss the possibility of observing Hawking radiation induced by the formation of a future event horizon, as well as the quantum entanglement properties of fluctuations excited together with the Hawking radiation.

References

[1]``Expanding edges of quantum Hall systems in a cosmology language: Hawking radiation from de Sitter horizon in edge modes'', M.Hotta, Y.Nambu, Y.Sugiyama, K.Yamamoto, G.Yusa, Phys.Rev.D **105**,105009 (2022).

[2]``Analog de Sitter universe in quantum Hall systems with an expanding edge'', Y.Nambu, M.Hotta, Phys.Rev.D **107**,085002 (2023).

[3]``Hawking radiation in quantum Hall system with an expanding edge: Application of anomaly method'', R. Yoshimoto, Y. Nambu, Phys. Lett. A **529**, 130100 (2025).