量子物理学・ナノサイエンス第 167 回セミナー

Thermodynamic entropy as a Noether invariant

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概　要

Entropy is a fundamental concept in physics. It appears in thermodynamics, statistical mechanics, information theory, computation theory, and thermodynamics of black holes. Recently, the inter-relations between different types of entropy have been discovered. By synthesizing various aspects of entropy, we thus obtain a deeper understanding of fundamental laws in physics. Now, there is a paper [1], which claims that black hole entropy is obtained as the Noether charge associated with the horizon Killing field. We are then naturally led to ask whether thermodynamic entropy of standard materials is also characterized by a Noether invariant.

In this seminar, we study a classical many-particle system with an external control represented by a time dependent parameter in a Lagrangian. We show that thermodynamic entropy of the system is uniquely characterized as the Noether invariant associated with a symmetry for an infinitesimal non-uniform time translation, where trajectories in the phase space are restricted to those consistent with quasi-static processes in thermodynamics [2]. The most remarkable result of our theory is the emergence of a universal constant of the action dimension, while our theory stands on classical mechanics, classical statistical mechanics, and thermodynamics.

Furthermore, we study a thermally isolated quantum many-body system with an external control represented by a time-dependent parameter. From unitary time evolution of quantum pure states, we derive an effective action for trajectories in a thermodynamic state space. In the action, the entropy appears with its conjugate variable. Especially, for saddle-point trajectories, the conjugate variable provides a time coordinate called thermal time. Then, the symmetry for the uniform translation of the thermal time emerges, which leads to the entropy as a Noether invariant [3].

[1] R. M. Wald, Phys. Rev. D **48** R3427 (1993).
[2] S. Sasa and Y. Yokokura, Phys. Rev. Lett. **116**, 140601 (2016).
[3] S. Sasa, S. Sugiura, and Y. Yokokura, in preparation.

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