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Heat conduction induced by non-Gaussian athermal fluctuations

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Recent experimental developments in single-molecule manipulation have enabled us to investigate the detailed thermodynamic properties of small systems such as colloidal and biological systems [1]. If the environments of the systems are in thermal equilibrium, stochastic thermodynamics with Gaussian noises is powerful to investigate universal relations in nonequilibrium statistical mechanics of small systems. On the other hand, the effects of non-Gaussian noises from athermal environments, reported in electrical circuits [2] and biomolecular systems [3], cannot be described by the conventional stochastic thermodynamics, because the environments are not in thermal equilibrium. Then, some natural questions arise: how can we describe the stochastic thermodynamics with the non-Gaussian noises, and how should the fundamental thermodynamic relations, such as the Fourier law and the heat fluctuation theorem, be modified with non-Gaussian noises?

In this presentation, we answer these questions with a stochastic model of heat conduction induced by non-Gaussian noises from athermal environments on the basis of stochastic energetics [4-6]. We consider a non-Gaussian model of Brownian motor and derive generalizations of the Fourier law and the heat fluctuation theorem. Moreover, we investigate the validity of the zeroth law of thermodynamics for athermal systems, and find that the zeroth law is not universally valid but depends on the details of a contact device between two systems. We numerically verify our results, which demonstrate that the direction of the average heat current depends on the characteristics of the heat conductor, and that the properties of the heat fluctuation significantly deviates from those of the conventional fluctuation theorem.

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