清华大学高等研究院

Institute for Advanced Study, Tsinghua University

学术报告

Title: **Nonequilibrium Steady States of Quantum Many-Body Systems: Heat Transport and "Hot Entanglement"***

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Venue: **Conference Hall 322, Science Building, Tsinghua University**

Abstract: Stationary states play a specially important role for nonequilibrium systems (NESS) as equilibrium states in canonical ensembles for statistical mechanics. Existence and uniqueness of a NESS for classical many body systems is a main theme of research by mathematical physicists for decades [1]. Answering this question for quantum many-body systems poses a major challenge for the present. While mathematical proofs of theorems for these basic issues are of great importance, being able to follow how these quantum systems evolve in time explicitly provides additional insights into its nonequilibrium properties. In a recent work [2] we use functional methods [2] to derive the quantum stochastic equations (master, Langevin, Fokker-Planck) for a prototypical quantum open system -- a harmonic chain in contact with two heat baths -- and by examining the energy flux relations in the open system, show the existence of NESS at late times. The functional method when combined with perturbative techniques can be used to explore quantum transport problems in nonlinear systems [3][4].

Another current topic on nonequilibrium quantum systems of theoretical interest and practical use (e.g., to quantum information processing) is "hot entanglement" [5] -- whether quantum entanglement can be maintained up to some high temperature. Galve et al [6] show that entanglement can be kept to a high temperature if the intra-system coupling is parametrically driven. To discern the true physical causes of a system's ability to sustain quantum entanglement at high temperatures we begin with two generic cases where the coupling between the two oscillators in the system is a constant: A model system S of two coupled oscillators interacting with a common thermal bath [7] and when each oscillator is coupled to its own bath, but kept at different temperatures [8]. The difference is that after S is fully relaxed, assuming weak coupling with the bath(s), the quantum system in the former case approaches thermal equilibrium, the latter case approaches a nonequilibrium steady state (NESS). We compare the entanglement in these systems at high temperatures (insignificant) and show their differences (significant).

*Based on recent work with J. T. Hsiang 项人宗 (Research Fellow, CTP, Fudan University) [2],[7],[8]

[1] E.g., Spohn, H. and J.L. Lebowitz, Comm.Math. Phys. 54, 97 (1977). Gallavotti, G. and E.G.D. Cohen, J. Stat. Phys. 80, 931 (1995). J.-P. Eckmann, Non-equilibrium steady states Beijing Lecture (2002).

[2] J. T. Hsiang and B. L. Hu, "Nonequilibrium Steady State in Open Quantum Systems: Influence Action, Stochastic Equation and Power Balance" Annals of Physics [arXiv:1405.7642v2]

[2] E. Calzetta and B. L. Hu, Nonequilibrium Quantum Field Theory (Cambridge University Press, 2008).

[3] S. Lepri, R. Livi, and A. Politi, "Thermal conductivity in classical low dimensional lattices", Phys. Rep. 377, 1 (2003).

[4] A. Dhar, "Heat transport in low-dimensional systems", Adv. Phys. 57, 457 (2008).

[5] V. Vedral, "Quantum Physics: Hot Entanglement" Nature 468, 769 (2010).

[6] F. Galve, L.A. Pachon and D. Zueco, "Bringing entanglement to the high temperature limit", Phys. Rev. Lett. 105, 180501 (2010). [7] J. T. Hsiang and B. L. Hu, "Hot Entanglement"? -- A Nonequilibrium Quantum Field Theory Scrutiny [arXiv:1506.02941] [8] ibid, "Quantum Entanglement at High Temperatures?-- Bosonic Systems in Nonequilibrium Steady State" [arXiv:1503.03587]