Frontier of Statistical Physics and Information Processing 2013

Full counting statistics of heat transport in harmonic systems and quantum fluctuation theorems

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We study the statistics of heat (Q_L) transferred in a given time interval t_M, through a finite harmonic chain, which is connected with two heat baths, maintained at different temperatures. We obtain the cumulant generating function (CGF) employing two-time quantum measurement scheme and non-equilibrium Green's function method. The CGF is expressed in terms of Green's functions of the system and a counting field dependent self-energy for the lead with shifted contour time arguments, $\Sigma^A(\tau,\tau') = \Sigma_L\big(\tau + \hbar x(\tau), \tau' + \hbar x(\tau')\big) - \Sigma_L(\tau,\tau')$, where $\Sigma_L(\tau,\tau')$ is the contour-ordered self-energy of the left lead. The expression of CGF is valid in both transient and steady state regimes. We find that, in general, the effect of energy measurement for counting heat is related to the time-translation for the self-energy whereas the counting of particle number, such as for electrons, the effect is to generate a phase for the self-energy. We present results for the first four cumulants of heat for graphene junction and for one atom harmonic junction. In the steady state we show that the CGF satisfy *"steady state fluctuation theorem"* where Kubo-Martin-Schwinger (KMS) boundary condition plays a key role. We also extend this formalism for multi-terminal setup and study *"exchange fluctuation theorems"* for weak and strong system-bath coupling.

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