A path integral theory of heat flow through a system of qubits

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Jukka is a pioneer in measuring heat in small quantum systems, the core physics of the field now usually called Quantum Thermodynamics. It is a pleasure to report on on-going work to apply path integrals techniques to these problems.

The starting point is to define heat as energy changes in an environment interacting with the system; the generating function of such energy changes can be written as a functional of system variables only. When the environment is a bosonic bath (harmonic oscillators interacting linearly with the system) these functionals are of the same type as the Feynman-Vernon influence functionals, and have been given explicitly by us, and by others (Aurell & Eichhhorn 2015, Aurell 2018). One can apply these functionals to a system of qubits interacting among themselves as in quantum annealing, and with the bath through the z-components of spin. The path integrals of the spin system dynamics can then be formulated as in the spin-boson problem. Quantum heat is in this setting described by generalizations of the functionals first introduced by Leggett and collaborators i.e. as interactions between"blips" and sojourns".

The results for system evolution by the "non-interacting blip approximation" (NIBA) of Leggett and collaborators can also be found, with much less work, by a polaron transform. The approximate evolution obtained this way is an expansion in small tuneling rate, in contrast to the more standard expansion in small system-bath interaction. The path integral approach to heat with corresponding NIBA-like approximations can similarly be seen as an expansion in small tuneling rate.

I will discuss some of the results obtained this way and questions for the future.

[1] E Aurell and R Eichhorn, "On the von Neumann entropy of a bath linearly coupled to a driven quantum system", New Journal of Physics, 17:065007 (2015)

[2] E Aurell, "Characteristic functions of quantum heat with baths at different temperatures " Phys. Rev. E 97, 062117 (2018)