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Precursors for a nonequilibrium theory of diffusion in open quantum systems

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The macroscopic fluctuation theory provides a complete hydrodynamic description of classical nonequilibrium diffusive systems. It remains an open question whether the hydrodynamic approach can capture diffusion in quantum systems or even whether enough quantumness is left in the hydrodynamic limit of non-unitary dynamics to justify pursuit of the theory. This talk explores the first step towards the formulation of such a theory. Furthermore, it provides evidence that a range of interesting models exhibiting diffusive dynamics and lasting quantum aspects at diffusive scales exists.

We introduce and explore the selective dephasing model (SDM). The SDM is an open quantum system studying the dynamics of free fermions, where part of the system is open to a dephasing environment (formulated as a Lindblad equation).

Coarse graining with respect to diffusive time and length scales lead to a set of diffusion equations of the conserved fields. Beside the expected local particle density, the other conserved fields are entanglement quantifiers, suggesting a non-local diffusion equation.

Furthermore, the steady state of the model maintains finite entanglement of the same scale as the density. The above results suggest a large set of interesting models, exhibiting both lasting entanglement as well as diffusive dynamics at the coarse grained limit. Moreover, we find that to go beyond the macroscopic fluctuation theory, one must consider non-local diffusion equation. A long list of fundamental concepts in diffusion physics now require revisiting: the Einstein relation, fluctuation theorems and the local structure of Fick's law to name a few. Hence, the SDM provides a minimal model to study the general rules governing the behavior of quantum diffusive systems with long ranged entanglement.

Reference

1. O. Shpielberg: *Diffusion and entanglement in open quantum systems*. Europhysics Letters **129**, 60005 (2020).