Geometry of dissipative driven phase transitions

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We explore the geometrical properties of reservoir-induced phase transitions of lattice fermions in a non-equilibrium steady-state of an open system with local reservoirs. We confine ourselves to a class of models quadratic in the Lindbladian evolution which admits Gaussian fermionic states as steady state solutions. These systems may become critical in the sense of a diverging correlation length on changing the reservoir coupling[1-3]. We will introduce the quantum Fisher tensor[4](QFT) as a mean to explore the geometrical and topological features of such systems. The QFT is a mixed state generalisation of pure state quantum geometric tensor. Similarly to the latter, the QFT induces a geometrical structure in the manifold of the quantum states: its symmetric part defines a metric, the Bures metric, whereas its antisymmetric part induces a symplectic structure on the same manifold, which is related to the Uhlmann-Berry curvature.

We show that the imaginary part of the QFT is sensitive to the presence of non-equilibrium phase transitions. Indeed, in analogy with Halmitonian quantum phase transitions, non-equilibrium criticalities can be associated with a vanishing gap in the damping spectrum, and correspondingly, with a point of non-analicity in the parameter space of the steady-state solutions. Such a point of non-analicity induces a non-trivial geometrical structure in the steady-state manifold, which can be observed through the Uhlmann-Berry phase. Indeed, we show that both real and imaginary part of the QFT diverge super-extensively with the system size in critical regions, and that their scaling behaviour provides a mapping of the phase diagram. Moreover, in systems with translationally invariant symmetries we analytically demonstrate how discontinuities in the imaginary part of the QFT, in the thermodynamical limit, uniquely identify regions of diverging correlation lengths.

Thanks to its differential-geometric and information-theoretic nature, the QFT provides insights into dissipative quantum critical phenomena, as well as new and powerful tools to explore them.

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