Physics of non-equilibrium open many-body systems

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The field of condensed matter physics is currently witnessing a paradigm shift towards expanding its interests to systems driven out-of-equilibrium. Such non-equilibrium matter offers a fundamentally unique opportunity to explore exotic states of matter and universality beyond the equilibrium paradigm and has potential applications to design new devices. On one hand, this is fueled by the rapid development of experimental techniques to control the dynamics of quantum many-body systems, such as driven electron systems, cavity QED, superconducting circuits, cold atoms, trapped ions, and polariton condensates, where the dissipation of particles from the system is compensated by an incoherent pumping [1]. On the other, classical active systems serve as another important class of out-of-equilibrium systems [2]. Here, the system is composed of "living" agents each of which consume energy. Examples include flocks of birds, school of fish and collection of cells or robots.

In this lecture, I aim to review the recent developments in the field of open quantum/classical many-body systems. I will first introduce the basics of a theoretical framework to treat these systems. I will then apply this framework to several problems in exciton polariton condensates [3, 4] and active classical systems [5, 6] to show that universal features and phase transitions with no equilibrium counterparts appear. In particular, I will show that the driven-dissipative nature of these systems may give rise to (1) Kardar-Parisi-Zhang scaling [7] that was first discussed in the context of randomly growing interfaces and (2) non-equilibrium phase transitions with their critical point characterized by the coalescence of eigenmodes (i.e., the so-called an exceptional point in the field of non-Hermitian quantum mechanics).

References

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