Critical exceptional point in a driven-dissipative coupled condensate

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Critical phenomena arise ubiquitously in various context of physics. Usually, these phenomena are associated with the softening of the massive. Here, we propose a novel, nonequilibrium-induced mechanism of critical phenomena driven by the *coalescence* of the eigenmodes, that may arise in driven-dissipative many-body systems with coupled order parameters, such as polariton condensates and driven-dissipative Bose-Einstein condensates in a double-well potential.

In our previous work, we have shown that a lower-to-upper branch condensate transition may be induced by the non-Hermitian nature of a coupled driven-dissipative condensate [1] (Fig. 1), proposing a new interpretation to the phase transition observed in some polariton experiments in the U(1)-broken phase (the so-called "second threshold" [2]). Interestingly, as shown in the figure, we have found that the phase boundary has an endpoint, marked by the so-called exceptional point (which we call the "critical exceptional point, CEP"), where the lower- and upper- branch condensate solutions coalesce.

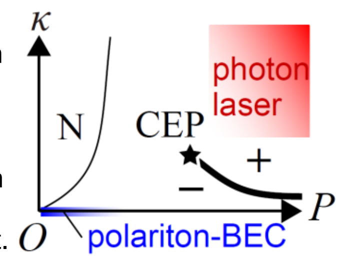

Fig. 1: Schematic phase diagram (as a function of the pump power P and photon decay rate κ) proposed in Ref. [1]. The thick solid line represents the phase boundary within the condensed phase. Here, "$-(+)$" represents the "$-(+)$"-solution phase, "N" represents the normal phase, and "CEP" is the critical exceptional point.

In this work [3], we investigate the critical properties of CEP. We show that the critical fluctuations arise at the CEP due to the coalescence of the collective eigenmodes that converts all the thermal and dissipative noise activated fluctuations to the Goldstone mode, leading to anomalously giant phase fluctuations that diverge at spatial dimensions d≤4 (Fig. 2). By performing a renormalization group analysis to the coupled-KPZ-like equations, we find that this anomalous feature leads to the rise of a strong-coupling fixed point at dimensions as high as d≤8.

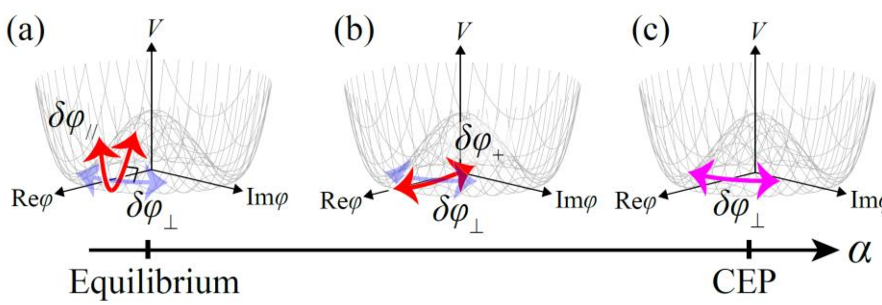

Fig. 2: Schematic explanation of the criticality of CEP. In the equilibrium limit (a), the two eigenmodes are given by the longitudinal ($\delta\varphi_{//}$) and transverse ($\delta\varphi_{\perp}$) modes. As the system approaches CEP by varying the parameter α, these modes ($\delta\varphi_{+}$ and $\delta\varphi_{\perp}$) become non-orthogonal (b), until they coalesce at CEP (c), leading to anomalously giant phase fluctuations.

References

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[3] R. Hanai and P. B. Littlewood, in preparation.