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Slow round-trip variations across quantum and classical critical points

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We address the out-of-equilibrium dynamics of many-body systems subject to time-dependent round-trip protocols across quantum and classical (thermal) phase transitions.

They are realized by slowly changing one relevant parameter w across its critical point $w_c = 0$, linearly in time with a large time scale t_s , from $w_i < 0$ to $w_f > 0$ and then back to $w_i < 0$, thus entailing multiple passages through the critical point.

Analogously to the one-way Kibble-Zurek protocols across a critical point, round-trip protocols develop dynamic scaling behaviors at both classical and quantum transitions, put forward within renormalization-group frameworks. The scaling scenario is analyzed within some paradigmatic models undergoing quantum and classical transitions belonging to the two-dimensional Ising universality class, such as one-dimensional quantum Ising models and fermionic wires, and two-dimensional classical Ising models (supplemented with a purely relaxational dynamics).

While the dynamic scaling frameworks are similar for classical and quantum systems, substantial differences emerge due to the different nature of their dynamics, which is purely relaxational for classical systems (implying thermalization in the large-time limit at fixed model parameters), and unitary in the case of quantum systems.

In particular, when the critical point separates two gapped (short-ranged) phases and the extreme value $w_f > 0$ is kept fixed in the large-ts limit of the round-trip protocol, we observe hysteresis-like scenarios in classical systems, while quantum systems do not apparently develop a sufficiently robust scaling limit along the return way, due to the presence of rapidly oscillating relative phases among the relevant quantum states.

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