

# Metrological bounds on scrambling dynamics in many-body quantum critical systems

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## Abstract

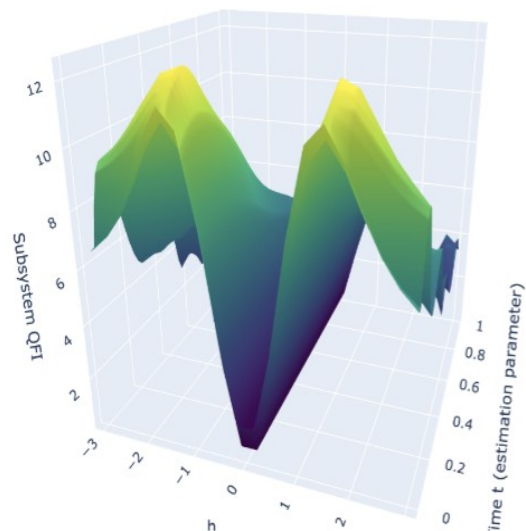
We present a quantum-information approach to many-body dynamics that connects chaos, information scrambling, and quantum criticality to operational quantifiers with direct relevance for quantum simulation. Starting from a general quantum Cramér–Rao framework for many-body systems, we develop bounds and diagnostics that relate the growth of subsystem quantum Fisher information to Lyapunov-type behavior in information scrambling, providing a metrological perspective on the emergence of effective chaos in closed quantum dynamics. This connection offers an experimentally meaningful route to quantify scrambling using accessible observables and reduced-state information, and it clarifies how locality, subsystem size, and conservation laws constrain the dynamical build-up of sensitivity. Within this framework, we show how scrambling indicators can exhibit enhanced growth and a pronounced peak in the vicinity of quantum critical points, offering a unified explanation for trends observed previously in the literature and linking dynamical signatures to phase structure. We discuss numerical strategies to extract growth rates, finite-size scaling, and crossover behavior across integrable, chaotic, and near-critical regimes, and we outline how the same toolbox can be adapted to realistic settings including coarse-grained

measurements and noise. Overall, these results connect quantum information, quantum metrology, and many-body physics in a single language, and provide practical diagnostics for near-term experiments and simulators aiming to probe scrambling and critical dynamics.

## References

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## Figures



**Figure 1:** 3D plot of subsystem QFI of the non-integrable transverse field Ising model with time  $t$  as the estimation parameter for a range of values of  $h$ .

