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Kibble-Zurek mechanism and beyond

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Crossing a continuous phase transition results in the formation of topological defects with a density predicted by the Kibble-Zurek mechanism (KZM). We report on two predictions beyond KZM:

First, it is shown that the statistics of defects follow a binomial distribution with N Bernoulli trials associated with the probability of forming a topological defect at the locations where multiple domains merge. All cumulants of the distribution are predicted to exhibit a common universal power-law scaling with the quench time in which the transition is crossed. Knowledge of the distribution is used to discuss the onset of adiabatic dynamics and bound rare events associated with large deviations.

Second, we characterize the spatial distribution of point-like topological defects in the resulting nonequilibrium state and model it using a Poisson point process in arbitrary spatial dimensions with KZM density. In one-dimensional systems, defect-defect correlations are enhanced and can be taken into account by considering the finite size of defects. The theory is expected to accurately reproduce the spacing distribution in higher dimensions, as we have shown in a two-dimensional setting, where the remaining deviations are attributed to coarsening. Our results are amenable to experimental tests with established technology, exploiting any of the platforms previously used to probe KZM scaling, provided it is endowed with spatial resolution, as is the case with trapped-ion systems, colloidal monolayers, multiferroics, ultracold gases in various geometries, and quantum simulators, to name some prominent examples.

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Primary author: DEL CAMPO, Adolfo (University of Luxembourg)

Presenter: DEL CAMPO, Adolfo (University of Luxembourg)

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