Symmetry Breaking and Topological Defect Formation in Ion Coulomb Crystals

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Structural defects in ion Coulomb crystals (kinks) have been proposed for studies of quantum-mechanical effects with solitons and as carriers of quantum information [1]. Defects form when a symmetry breaking phase transition is crossed and the finite speed of information prevents different regions from coordinating the choice of the symmetry broken state. Where such local choices are incompatible, defects will form with densities predicted to follow a power law scaling in the rate of the transition. The importance of this Kibble-Zurek mechanism (KZM) ranges from cosmology to condensed matter [2]. In previous tests in homogeneous systems, defect formation was seen, but weak dependence on the transition rate and limited control of external parameters so far prevented tests of KZM scaling. As recently predicted [3], in inhomogeneous systems propagation of the critical front enhances the role of causality and steepens scaling of defect density with the transition rate. We use ion Coulomb crystals in a harmonic trap to demonstrate, for the first time, scaling of the number of topological defects with the transition rate – the central prediction of KZM - in a well-controlled environment [4]. We will detail on kink dynamics [5] and stability in our system. Implementing mass defects and electric fields we demonstrate first steps to a controlled kink preparation and manipulation for future studies of nonlinear physics in ion Coulomb crystals.

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[2] Kibble, T.W.B., *Phys. Rep.* 67, 183 (1980); Zurek, W. H., *Nature* 317, 505 (1985)
[3] del Campo et al., *Phys. Rev. Lett.* 105, 075701 (2010)
[4] Pyka et al., *Nat. Commun*. 4, 2291 (2013)
[5] Partner et al., *New J. Phys.* (2013)