Critical Behavior and Collective Modes at the Superfluid Transition in Amorphous Systems

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We investigate the critical behavior and the dynamics of the amplitude (Higgs) mode close to the superfluid-insulator quantum phase transition in an amorphous system (i.e., a system subject to topological randomness). In particular, we map the two-dimensional Bose-Hubbard Hamiltonian defined on a random Voronoi-Delaunay lattice onto a (2+1)-dimensional layered classical XY model with correlated topological disorder. We study the resulting model by laying recourse to classical Monte Carlo simulations. We specifically focus on the scalar susceptibility of the order parameter to study the dynamics of the amplitude mode. To do so, we harness the maximum entropy method to perform the analytic continuation of the scalar susceptibility to real frequencies. Our analysis shows that the amplitude mode remains delocalized in the presence of such topological disorder, quite at odds with its behavior in generic disordered systems, where the randomness localizes the Higgs mode [1]. Furthermore, we show that the critical behavior of the topologically disordered system is identical to that of its translationally invariant counterpart, consistent with a modified Harris criterion [2]. This suggests that the localization of the collective excitations in the presence of disorder is tied to the critical behavior of the quantum phase transition rather than a simple Anderson-localization-type interference mechanism [3].

T.V. acknowledges support from the National Science Foundation under Grants No. DMR-1828489 and OAC-1919789 as well as Grants No. PHY-1748958 and PHY-2309135. P.K.V. acknowledges support via the IIE Travel award by the Global Engagement Office, IIT Madras. R.N. and P.K.V. also acknowledge funding from the Center for Quantum Information Theory in Matter and Spacetime, IIT Madras and from the Department of Science and Technology, Govt. of India, under Grant No. DST/ICPS/QuST/Theme-3/2019/Q69, as well as support from the Mphasis F1 Foundation via the Centre for Quantum Information, Communication, and Computing (CQuICC).

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