MAR14-2013-020127

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Exciton reactions on carbon nanotubes: an experimental testbed for critical dynamics[1]

JEREMY ALLAM, Advanced Technology Institute and Department of Physics, University of Surrey, Guildford GU2 7XH, United Kingdom

The one-dimensional coalescing random walk ($X + X \to X$) is a paradigmatic reaction-diffusion system due to both its exact solvability [1,2] and the experimental observation of nonclassical kinetics at asymptotically long times [3]. The solvability rests on the anticommutative property of intersecting trajectories of particles that react *instantly* and at *short range*: however, the validity of these assumptions in real systems has not previously been tested by experiment. We have shown that exciton-exciton recombination (fusion) on carbon nanotubes provides a platform for quantitative studies of critical kinetics in a simple non-equilibrium system [4]. Under high excitation density we observed a crossover in the exciton density n between regimes of classical ($n \propto t^{-1}$) and anomalous ($n \propto t^{-1/2}$) scale invariance as predicted by renormalization group [5] and approximate [1] theories, arising from a finite reaction probability of ≈ 0.2 per encounter. At long times the exciton population per nanotube exponentially approaches unity (i.e. a finite size effect), allowing calibration of the exciton density and hence a demonstration of universality extending over both classical and critical regimes. Under low excitation, the early kinetics followed a Smoluchowski-Noyes form $dn/dt \propto n^2 t^{-1/2}$ rather than the asymptotic $dn/dt \propto n^3$, providing direct evidence for the spatial self-ordering that precedes critical scale invariance. We studied the re-emergence of microscopic detail at the classical-nonclassical crossover, which is abrupt and nonmonotonic due to competition between temporal and spatial averaging of critical fluctuations (i.e. finite reaction rate and range). It appears that real-world experiments will require more complete descriptions of the interactions than is available in existing models.

[1] D. Ben-Avraham and S. Havlin, *Diffusion and Reactions in Fractals and Disordered Systems* (Cambridge University Press, Cambridge, 2000).
[2] G. M. Schütz, Phase Transitions and Critical Phenomena 19, 1 (2001).
[3] J. Prasad and R. Kopelman, Phys. Rev. Lett. 59, 2103 (1987).
[4] J. Allam et al., Phys. Rev. Lett. 111, 197401 (2013).
[5] U. C. Täuber et al., *J. Phys. A: Math. Gen.* 38, R79–R131 (2005).

[1]This work was supported by the UK Engineering and Physical Sciences Research Council "Next Generation Electrophotonics" programme (Grants No. EP/C010531/ 1 and No. EP/C010558/1).