The KPZ universality conjecture: Old ideas and new applications

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The first wave of research on the statistical physics of growth processes took off with the publication of the KPZ paper in 1986, which unified a large variety of stochastic growth models into a single universality class characterized by two scaling exponents [1]. Five years later it was recognized that a refined characterization of the KPZ class is possible by combining simulations of growth models with a systematic scaling analysis [2]. This work showed for the first time that the universal amplitudes associated with the interfacial fluctuations depend on the initial condition of the process. Specifically 'flat' and 'stationary' initial conditions were considered, but the existence of a further ('curved') universality class was also hinted at. The KPZ scaling theory is essentially a sophisticated kind of dimensional analysis and makes use of the KPZ equation only as a bookkeeping device [3].

After explaining the basic idea and outlining the historical development, the talk will focus on recent applications of KPZ theory in the context of biological evolution in spatially distributed populations. As an introductory example, the superdiffusive scaling of the boundaries of mutational sectors in growing bacterial colonies will be described, which provides a clear experimental signature of KPZ behavior in this archetypical growth system [4]. We then consider a setting where the role of the KPZ height function is played by the (logarithmic) fitness of the evolving population [5, 6]. On a conceptual level, the analogy to surface growth leads to the important insight that the speed of adaptation decouples from the fitness variation, leading to an apparent breakdown of R.A. Fisher's 'fundamental theorem' derived for well-mixed populations [6, 7]. Using extensive simulations, we show that the three classes of geometry-dependent KPZ universality can be recovered even when the selection coefficient of beneficial mutations (which gives rise to the KPZ nonlinearity in this case) is realistically small. Finally, in the presence of deleterious mutations the system undergoes a phase transition in the directed percolation universality class which is related to nonequilibrium wetting [8]. This part of the talk is based on joint work with Jakub Otwinowski.

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