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Spatial shape of avalanches in the Brownian force model. (English summary)

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Everyone knows and has seen an avalanche phenomenon. It is ubiquitous and diverse in nature, such as in sand pile collapses, the strike-ship faults in geophysics, and the motion of soft magnetic domain walls. Avalanches are defined as the collective jumps of the particles in response to the external driving, which normally occur when there is interface between two disordered media. The physics of avalanches is fascinating and extremely challenging due to the many degrees of freedom. Despite much effort poured into this subject, only a few exact results have been obtained. At the heart of the problem is how to describe the particle motion driven by random forces, especially when there is interface.

The theoretical and computational statistical-mechanics research by the authors studies the avalanche process in the Brownian force model (BFM), which has an exact solvable property for an interface. In their formulation, the BFM is investigated in the discrete setting with N points coupled by an elasticity matrix in a random medium, as well as in its continuum limit. An exact formula for the joint probability of jumps is derived for an arbitrary elasticity matrix and arbitrary monotonous driving. Consequently, it implies the joint density of local avalanche sizes for quasi-static stationary driving near the depinning threshold. The results obtained are surprisingly general and contain all the spatial statistics of avalanches, which will be useful to extract new information to be verified by experiments. For examples in the large-N limit, there exist two interesting regimes. One corresponds to the usual picture from mean-field depinning models, and the other highlights the intermittent nature of the avalanche motion.

The shape of the avalanches is emphasized and analyzed both in the discrete setting and in the continuum limit for an elastic line with short-ranged elasticity. From the saddle-point analysis, it is discovered that, in the large aspect ratios, the avalanche shape becomes deterministic, with small fluctuations which vanish in the limit. Moreover, the leading corrections to the mean shape as well as the fluctuation around the mean shape and shape asymmetry for finite aspect ratios are also obtained. In addition, while theoretical calculations are performed in some special cases, numerical simulations are carried in generality, and both results yield quantitatively consistent results and good agreement.

The article is clearly written, easily comprehensible and neatly organized. It provides a full explanation and interpretation in each part, and explains how the parts are connected together. Plenty of supplemental information is included in the appendices, which provide calculation details, verifications, and alternative methods. The mathematical details are not difficult; nor are the equations intimidating. The article is highly recommended for graduate students and researchers with interests in the fascinating subject of avalanches and statistical mechanics. *Sujin Suwanna*