Dynamical transition in the relaxation of elastic strings at finite temperatures

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The physics of elastic surfaces in disordered media has received much attention in the last decades. It is well known that at zero temperature the interfaces undergo a pinning-depinning phase transition at a critical value of the external driving force, F_c. But the introduction of thermal fluctuations substancially changes this behaviour. For low driving forces, high temperatures make the system move freely *(flow regime)*. At very low T, on the other hand, there are long periods of inactivity during which the interface is trapped in metastable states, followed by small bursts of activity *(creeping)*. Many different approaches have been taken to characterize this behaviour[1–3]. Most of them have been focused on the dynamics at very low T and on global properties of the interfaces. Here, instead, we are interested in studying the change that the dynamics suffers when the temperature increases. Our aim is to track the single-site activity and to investigate whether spatio-temporal long-range correlations are actually present or not at a certain temperature.

Description of the model

We employ a discrete model defined on a square lattice where each cell $[i, h]$ $(1 \leq i \leq L)$ is assigned a quenched disorder $\eta_{i,h}$ generated with a normal distribution N(0,1). We define the function V_i for each site (γ elastic constant, F driving force, and ξ_i Gaussian white noise).The interface configuration is updated simultaneously for all i at every time step, and the interface moves, $h_i(t + 1) \rightarrow h_i(t) + 1$, only if $V_i(t) > 0$, otherwise it remains pinned at i.

$$V_i(t) = \gamma[h_{i+1} - h_{i-1} - 2h_i)] + F + g \cdot \eta_{i,h_i} + \sqrt{T} \cdot \xi_i$$

General results

We observe that the relaxation dynamics has quite well differenciated behaviour for temperatures over and below an optimal temperature T_{opt}. First we analize the behaviour of the average velocity of the interface, $v(t) = \langle \Delta h/\Delta t \rangle$. For large values of T, the system relaxes exponentially fast towards an steady-state. When the temperature decreases the relaxation time becomes longer and longer. In the range of times studied, the relaxation of the velocity decays with a close to power-law functional form for T_{opt}. At even lower $T < T_{opt}$, the relaxation happens in burst of global activity between which the interface is trapped in local minima of the energy landscape, and then the evolution of v shows several plateaus.

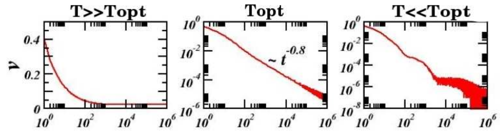

Figura 1. Evolution of average velocity for a L=16384 system

We also analize the activity patterns that are obtained for each of these temperature regimes, studying the temporal and spatial correlations. To study the time statistics we analize the first time return $P^{\tau}_{f}(\tau)$. At hight temperatures the inter-event times showing an exponential decay. At very low T, on the other hand, the interface slowly explores energetically favorable configurations and the longer is the time, the more unfrecuent the big burst become. According to this picture, $P^{\tau}_{f}(\tau)$ exhibit a bumpy structure with a series of characteristic values of the waiting times. In between these two extreme regimes, an interesting effect is observed. Around the optimal value of temperature T_{opt}, $P^{\tau}_{f}(\tau)$ decays as a power-law.

All this results evidence the presence of a transition in the relaxation dynamics of the string that could be related with the emergence of power-law scaling for several magnitudes.

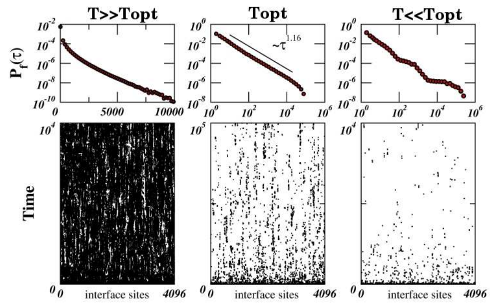

Figura 2. Activity plots for the three temperature regimes (active sites are drawn in black). *Top:* First time return distributions.

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