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Janićević, S.; Laurson, L.; Måløy, K. J.; Santucci, S.; Alava, M. J.

Janićević et al. Reply

Published in:
Physical Review Letters

DOI:
[10.1103/PhysRevLett.119.188901](https://doi.org/10.1103/PhysRevLett.119.188901)

Published: 31/10/2017

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Janićević, S., Laurson, L., Måløy, K. J., Santucci, S., & Alava, M. J. (2017). Janićević et al. Reply. *Physical Review Letters*, 119(18), 1-2. [188901]. <https://doi.org/10.1103/PhysRevLett.119.188901>

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Janićević *et al.* Reply: Recently, we proposed a general mechanism leading to power-law distributed waiting times separating avalanches measured in a crackling-noise signal, due to their detection procedure [1]. We demonstrated its applicability for experimental and numerical data on intermittent crack front dynamics. Ramos and Stojanova (RS) argue that this mechanism would only produce power-law distributed waiting times up to the time scale set by the longest event [2]. Thus, it could not explain power-law distributed waiting times in systems such as earthquakes exhibiting a separation of time scales between the longest waiting times and the duration of the longest observed events. We strongly disagree with their comment, and point out here their misunderstanding and mistakes.

First, it is important to underline the general character and importance of our results. Considering the critical depinning of elastic manifolds [3], relevant for a wide range of systems from Barkhausen noise to earthquakes [4,5], we derived a general scaling behavior for the waiting times between avalanches detected by thresholding a crackling noise signal. Such a procedure is always necessarily applied to subtract explicitly background noise, and/or implicitly due to the limited accuracy of measurement apparatus. We verified our scaling prediction by analyzing crack front propagation in disordered media, an archetypal example of a system displaying crackling dynamics. Interestingly, those experiments share many statistical properties with seismicity catalogs [6]; moreover, the numerical model describes a wide range of systems belonging to the same “universality class,” including contact line wetting dynamics and deformation of crystalline solids [7].

Based on the results of our Letter [1], we show in Fig. 1 how the cutoffs T_0 and $T_{W,0}$ of the avalanche duration and waiting time distributions, respectively, evolve with the threshold level V_{th} . Contrary to the wrong claim of RS, for large V_{th} , $T_{W,0}$ is more than an order of magnitude larger than T_0 for both experiments and simulations. RS confuse “real and true” avalanche events with the ones empirically detected. This confusion is probably due to the difficulty (or even the impossibility) of directly detecting those “true” events, the cutoff duration of which sets the maximum of the empirical $T_{W,0}$. At the critical point of the depinning phase transition [3,4], this time scale *diverges*, implying that a high enough V_{th} may result in an arbitrarily large time-scale separation between the empirical T_0 and $T_{W,0}$.

FIG. 1. Scaling of the cutoffs of the avalanche duration and waiting time distributions, T_0 and $T_{W,0}$, respectively, with the threshold level V_{th} for crack propagation experiments (left) and simulations of the crack line model (right).

Furthermore, RS claim that “there are no earthquakes with durations larger than a few minutes to be broken into subavalanches by a given threshold.” Unfortunately, this statement is also wrong, due to the very same confusion. Because of the limited accuracy of seismograms (among various other difficulties) [8], seismicity catalogs are only complete above a finite earthquake magnitude (estimated to be as high as 3 for the Southern California Seismic Network [9]): low levels of seismic activity below such magnitudes are not recorded in typical catalogs. Nevertheless, slow slip events, lasting several months, and also called “silent earthquakes” since imperceptible to seismograms, have been detected thanks to the use of GPS networks and shown to trigger large quake events [10].

Finally, RS propose “toughness correlations” as an alternative explanation for power-law distributed waiting times. However, the critical depinning dynamics we studied does not require structural correlations but arises from the interplay between elasticity, short-range correlated disorder, and slow external driving. Ultimately, the question of which mechanism is responsible for the empirical observations of interevent correlations in a given system should be tested in each case, e.g., by employing our scaling predictions as discussed after Eq. (1) of our Letter [1], since various mechanisms including inertial effects or viscoelasticity [11] could also play a role.

This research has been supported by the Academy of Finland through an Academy Research Fellowship (L. L., Project No. 268302) and through the Centres of Excellence Program (Project No. 251748). S. S. acknowledges the support of the Russian Government with Grant No. 14.W03.31.0002, and the support of CNRS with the LIA, “D-FFRACT”. K. J. M. acknowledges the support of the Norwegian Research Council through the Frinat Grant No. 205486. L. L. wishes to thank S. S. and CNRS for the hospitality during the invited researcher visit at ENS Lyon. We acknowledge the computational resources provided by the Aalto University School of Science “Science-IT” project.

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Received 12 May 2017; published 31 October 2017

DOI: [10.1103/PhysRevLett.119.188901](https://doi.org/10.1103/PhysRevLett.119.188901)

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