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A Stochastic Dynamics Model for Earthquake Rupture

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Stochastic models have successfully been used to describe the qualitative and quantitative behavior of systems in many natural domains, and have a great potential for the studies of earthquake physics since it is quite limited in dealing with complex and large-scale interactions using determinant methods.

We reveal that Langevin equations may play a fundamental role in interpreting the stochastic behavior of rupture processes in earthquakes. The simulation results of our stochastic model based on specific Langevin equations are able to qualify and quantify the characteristics of rupture models of earthquake events worldwide. We also show analytically that the Langevin equation gives out Truncated Exponential distributions (TEXs) as steady-state solutions, consistent with the study of Thingbaijam and Mai (Bull. Seismol. Soc. Am. (2016) 106 (4): 1802-1816.) and we relate the fitting parameter u_c in TEX functions to the ratio of the diffusional and damping coefficient in the Langevin equation.

Thingbaijam and Mai carried out a model-free analysis and formalize the empirical patterns of the slip distributions without physically based laws. The stochastic model we proposed for earthquake rupture intrinsically includes fluctuations as well as uncertainties in the random variables. We claim that during an earthquake, the stationary part of the rupture process is governed by the Langevin equation, and explain the features in the work of Thingbaijam and Mai as listed below via this point of view. (1) The parameter u_c of TEX scales with the average co-seismic slips, (2) the action of trimming to the rupture model improve its goodness-of-fit of TEX, and most important, (3) the truncated exponential probability distribution for earthquake slips.

The Langevin equation gives us implications and clues to investigate more about the physically-based laws underpinning the stochastic rupture process, while most of them are still left to be discovered for future work.