Effects of long range interactions in the Burridge-Knopoff earthquake model

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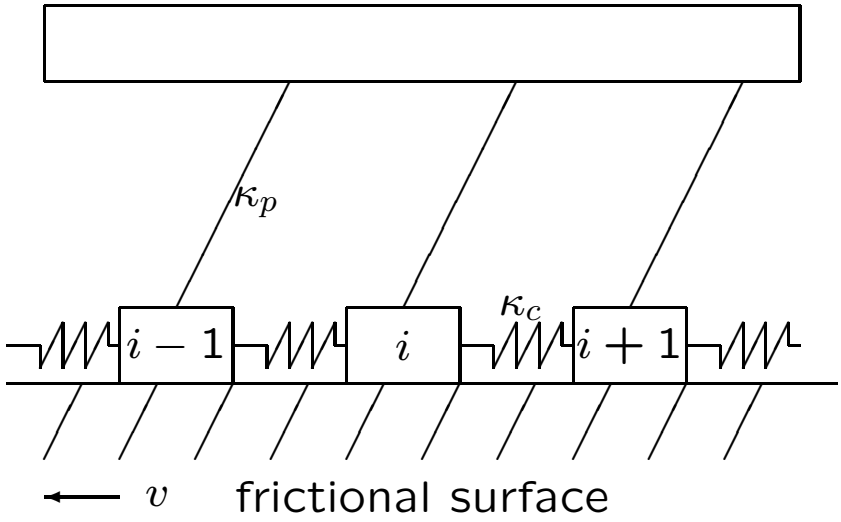
Burridge-Knopoff Model

Block-spring model representing a lateral fault



(Dimensionless) equation of motion:

$$\ddot{u}_j = \ell^2(u_{j+1} - 2u_j + u_{j-1}) - u_j - \phi(2\alpha\nu + 2\alpha\dot{u}_j)$$

Velocity-weakening friction force ϕ:

$$\phi(z) = \begin{cases} (1-\sigma)/(1+z/(1-\sigma)) & (z > 0) \\ (-\infty, 1] & (z = 0) \end{cases}$$

Four dimensionless parameters:
$\ell^2 = \frac{\kappa_c}{\kappa_p} = 100$, ν (loading velocity) $= 0$
α (dynamical friction parameter) $= 2.5$, $\sigma = 0.01$

velocity-weakening fricition force

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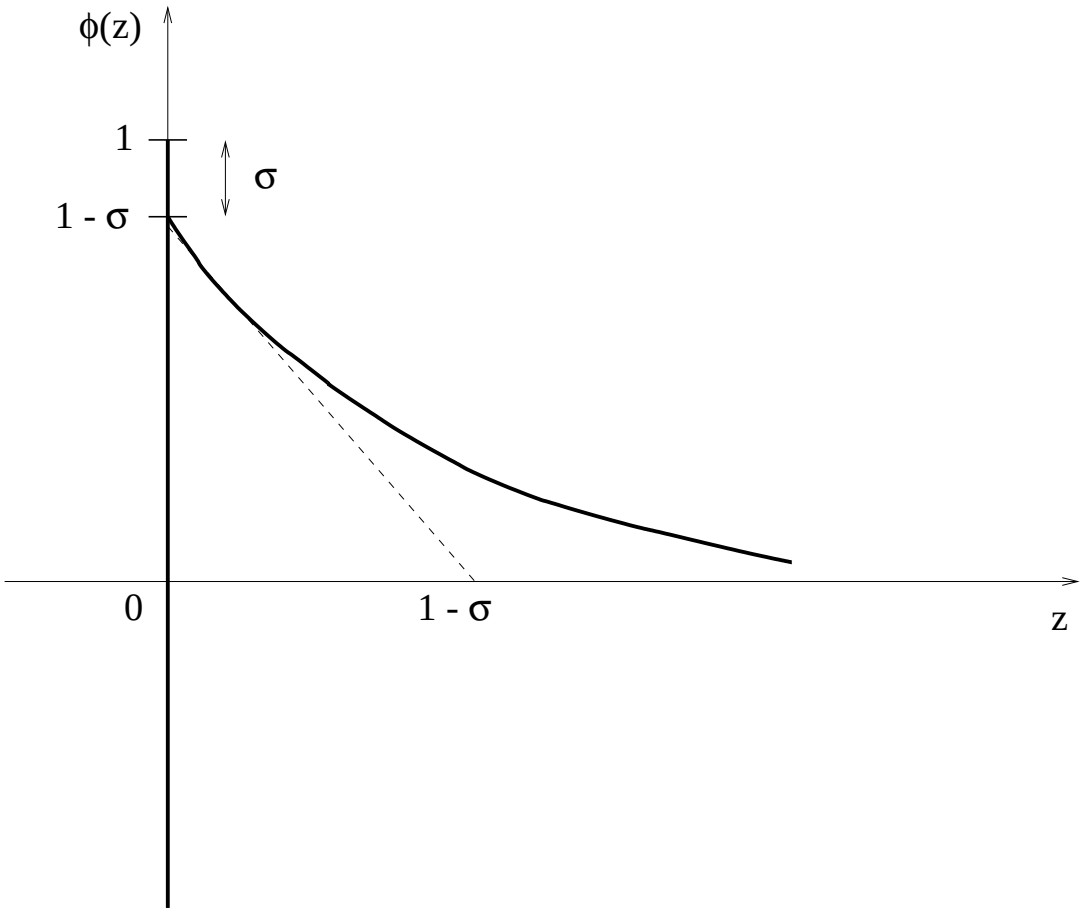


makes BK model describe a nonlinear driven dissipative threshold system.

Scaling of Events and Moments

According to Gutenberg and Richter, real earthquakes (moments) averaged over all faults obey

$$\#\text{ of events of size M} \sim M^{-b}$$

$b \cong 1.5 \sim 2$.

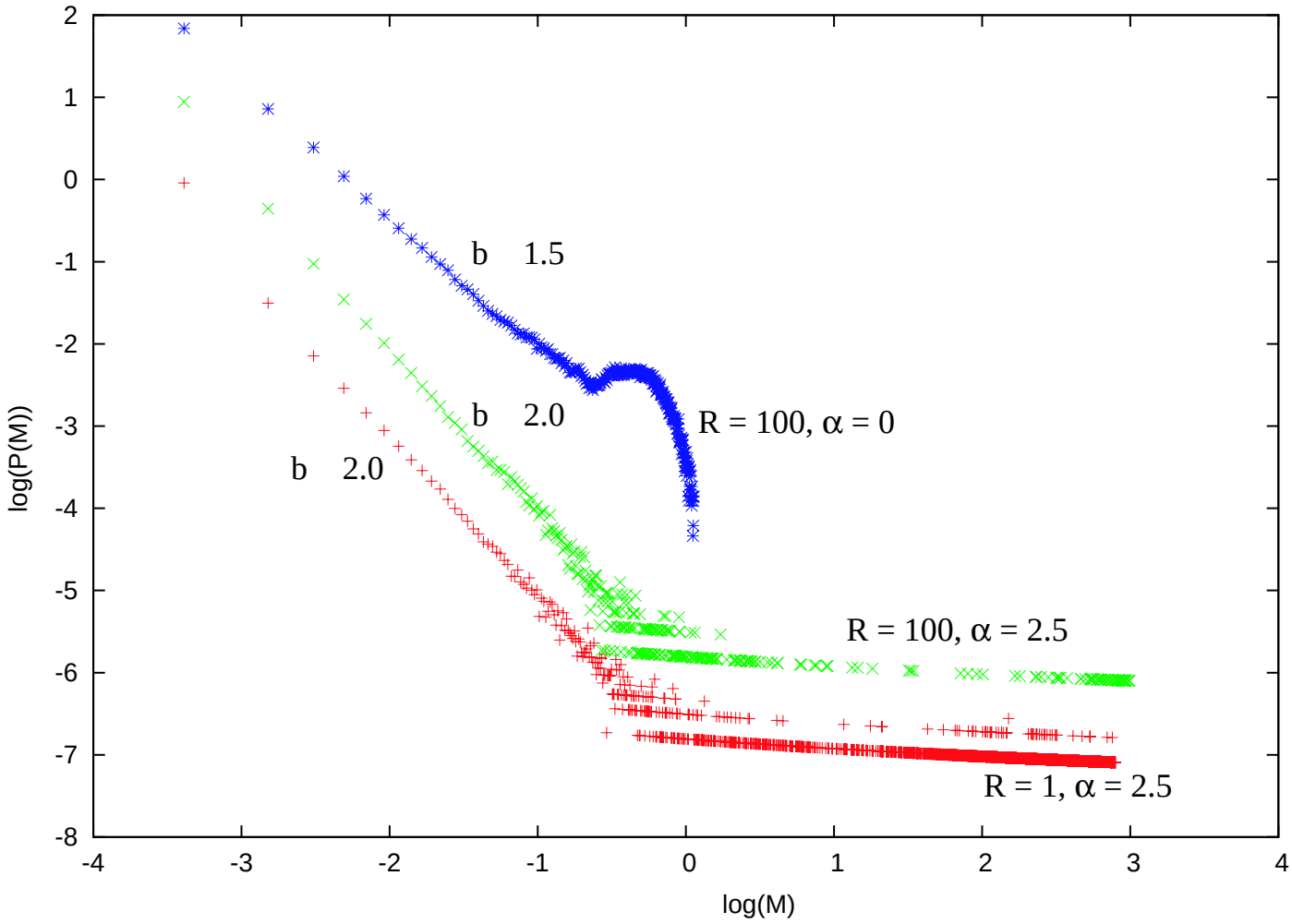
Carlson and Langer (1989) simulated the Burridge-Knopoff model and found limited scaling region ($b \approx 2.0$) for 1D nearest-neighbor model ($R = 1$).

What happens when interactions between blocks are long-range as in realistic faults?

An event is a group of moving blocks within the interaction range R. Moment of an earthquake:

$$M = \sum_j \delta u_j$$

δu_j is relative displacement of jth block to the substrate during an earthquake.



Moment distribution for various interation ranges R and α for $N = 1000$ with zero-loading-velocity limit. For $\alpha = 2.5$, mean-field result is not obtained by only increasing R. However, the slope of 1.5 for $\alpha = 0.0$ is consistent with the mean-field description of celluar automaton version of the model.

Summary

1. The moment distribution of earthquakes for $R = 1$ is similar to that found by Carlson and Langer. Only one scaling region corresponding to localized events is found.

2. At high values of the dynamical friction parameter, $\alpha = 2.5$, mean-field results are not obtained by increasing R only. The slope $b \approx 2$ is not understood.

3. For $\alpha = 0$, near-mean-field results are obtained by increasing R. The slope of 1.5 is consistent with the celluar automaton version of the model.