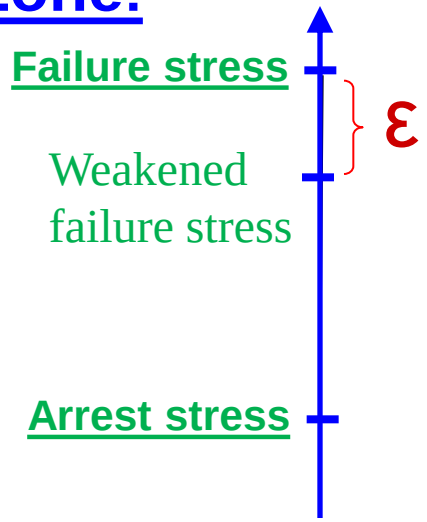
Coarse Grained Model for Slip Evolution in Heterogeneous Earthquake Fault Zone:

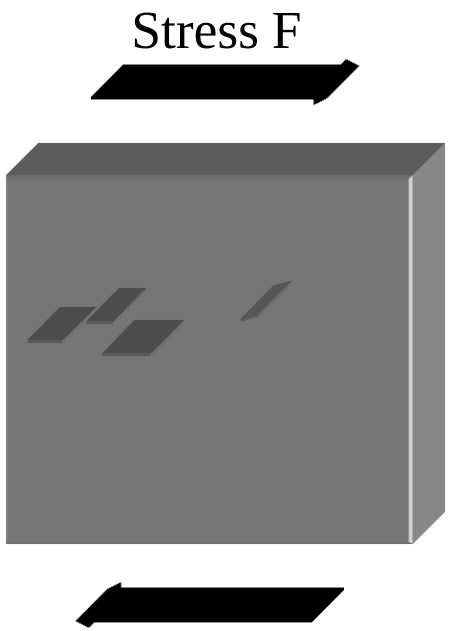


$$\eta\, \partial u(\mathbf{r},t)/\partial t = F + \sigma_{int}(\mathbf{r},t) - f_R[u, r, \text{history}]$$

Slip velocity ~ stress + interaction + Pinning due to heterogeneities

interaction:

$$\sigma_{int}(\mathbf{r},t) = \int_{-\infty}^{t} dt' \int d^d r'\; J(\mathbf{r}-\mathbf{r}', t-t') \times [u(\mathbf{r}',t') - u(\mathbf{r},t)]$$



Renormalization Group:

Interaction sufficiently long range

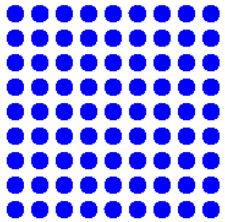
→ **MEAN FIELD THEORY** GIVES **EXACT RESULTS** !

Ben-Zion, Rice 1993

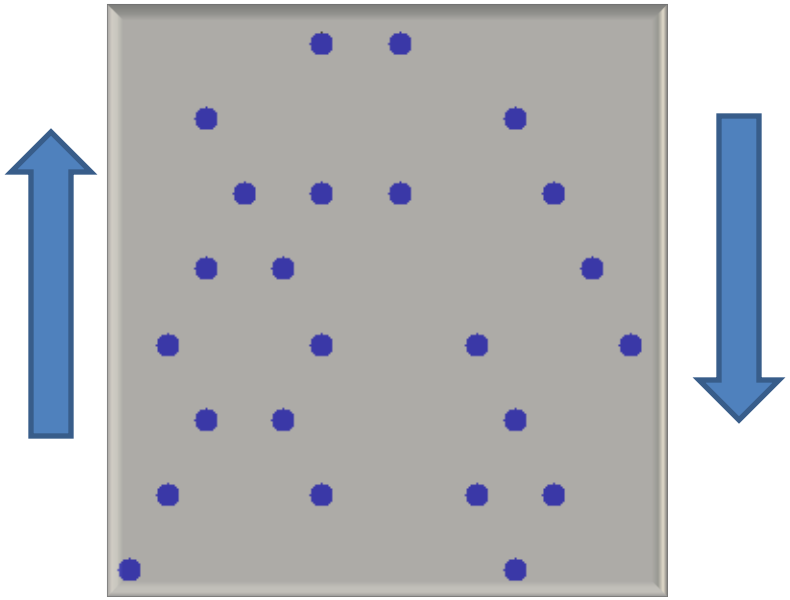
Fisher, KD, Ben-Zion, Ramathan Phys. Rev Lett.

Main Idea of the simple model:

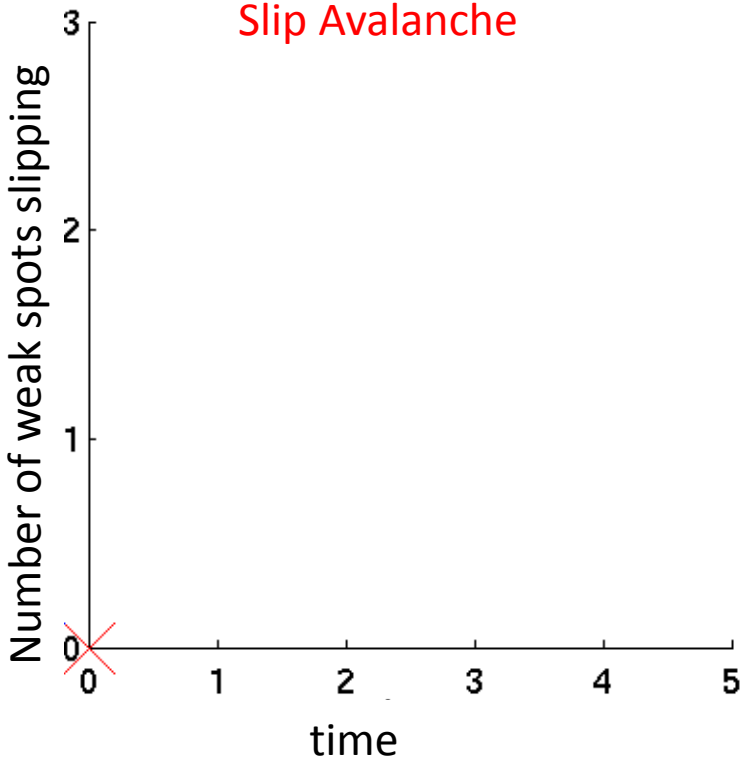
Shear material:



1. Weak spot slips → triggers other weak spots to slip
   Slip Avalanche
2. Repeat

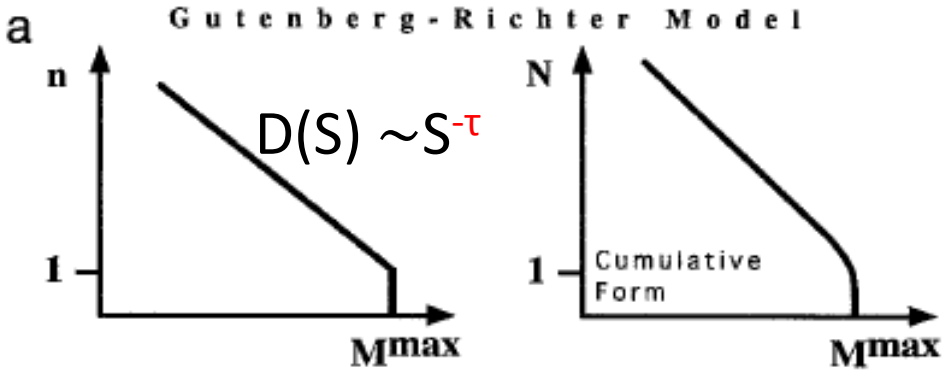


Slip Avalanche



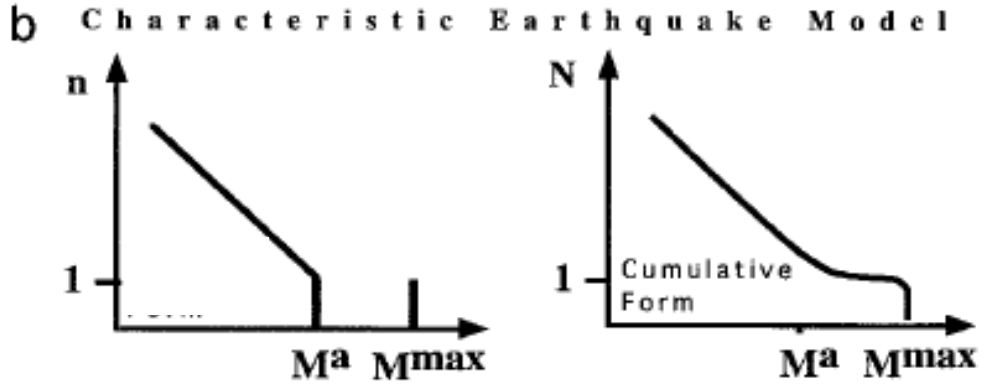
Gutenberg Richter exponent:

$\tau = 1.5$ (b=0.7-1.1)



Magnitude ~ 2/3 Log(total displacement)+ const

Characteristic Earthquake distribution (stick slip)



Young Faults

aperiodic

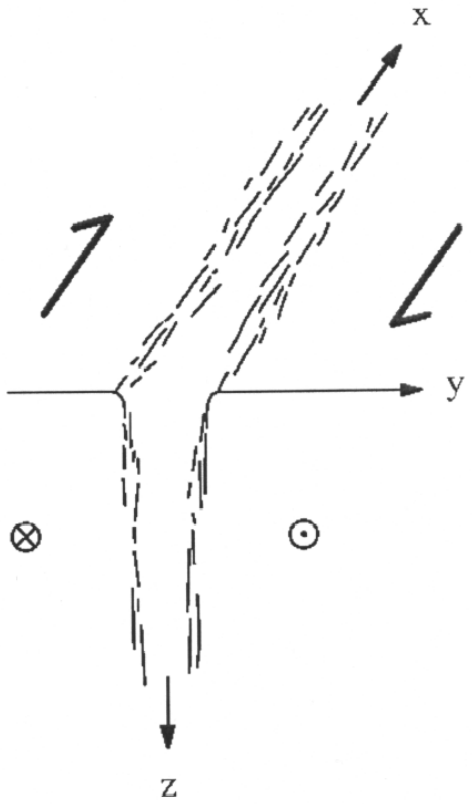
Modeled by ε=0

Or

Older Faults

Almost periodic

Modeled by ε > 0

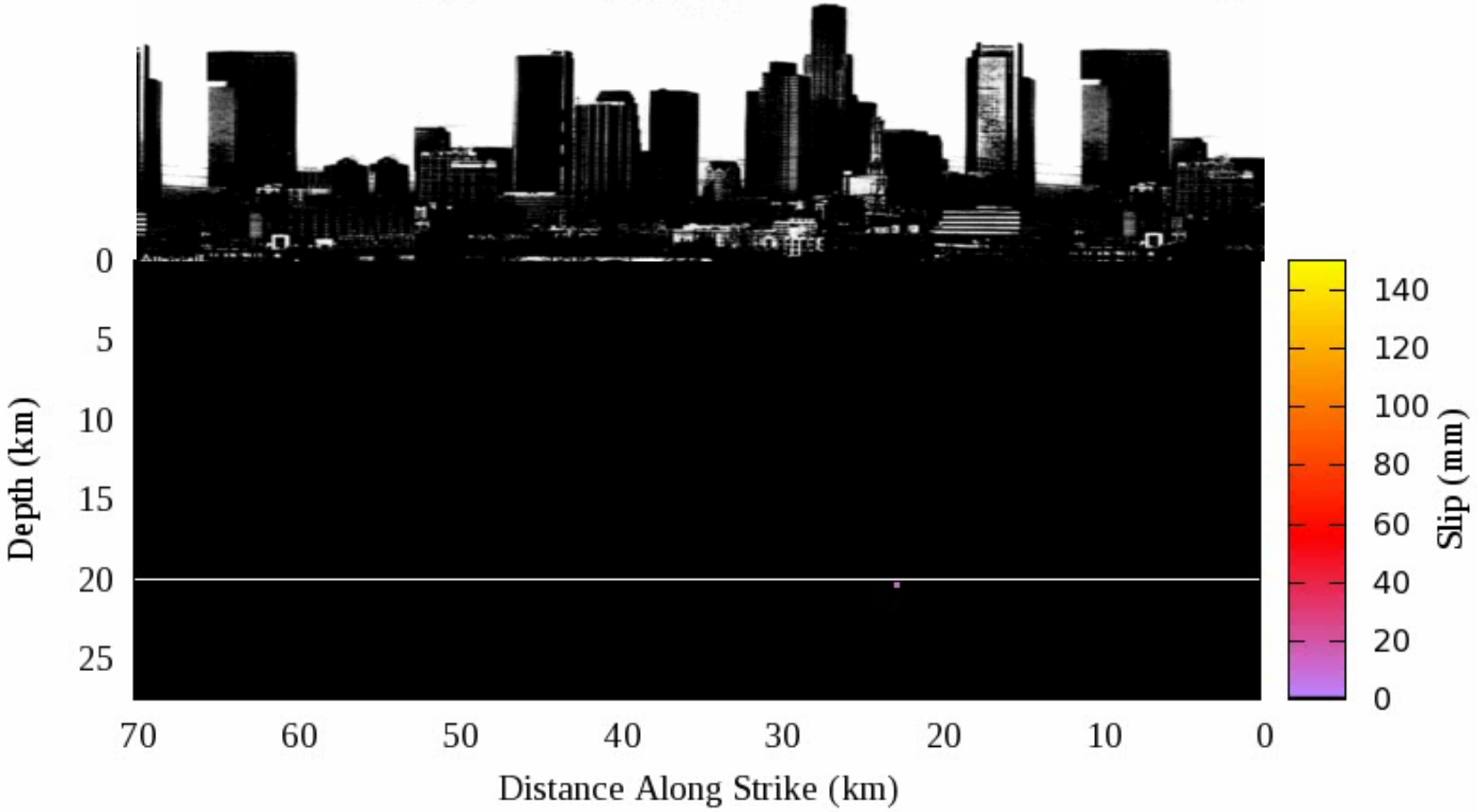


Braden Brinkman, Michael LeBlanc, J.T. Uhl, Y. Ben-Zion, KD, 2013, Fisher, KD, Ben-Zion, Ramathan 1996, Ben-Zion, Rice 1993

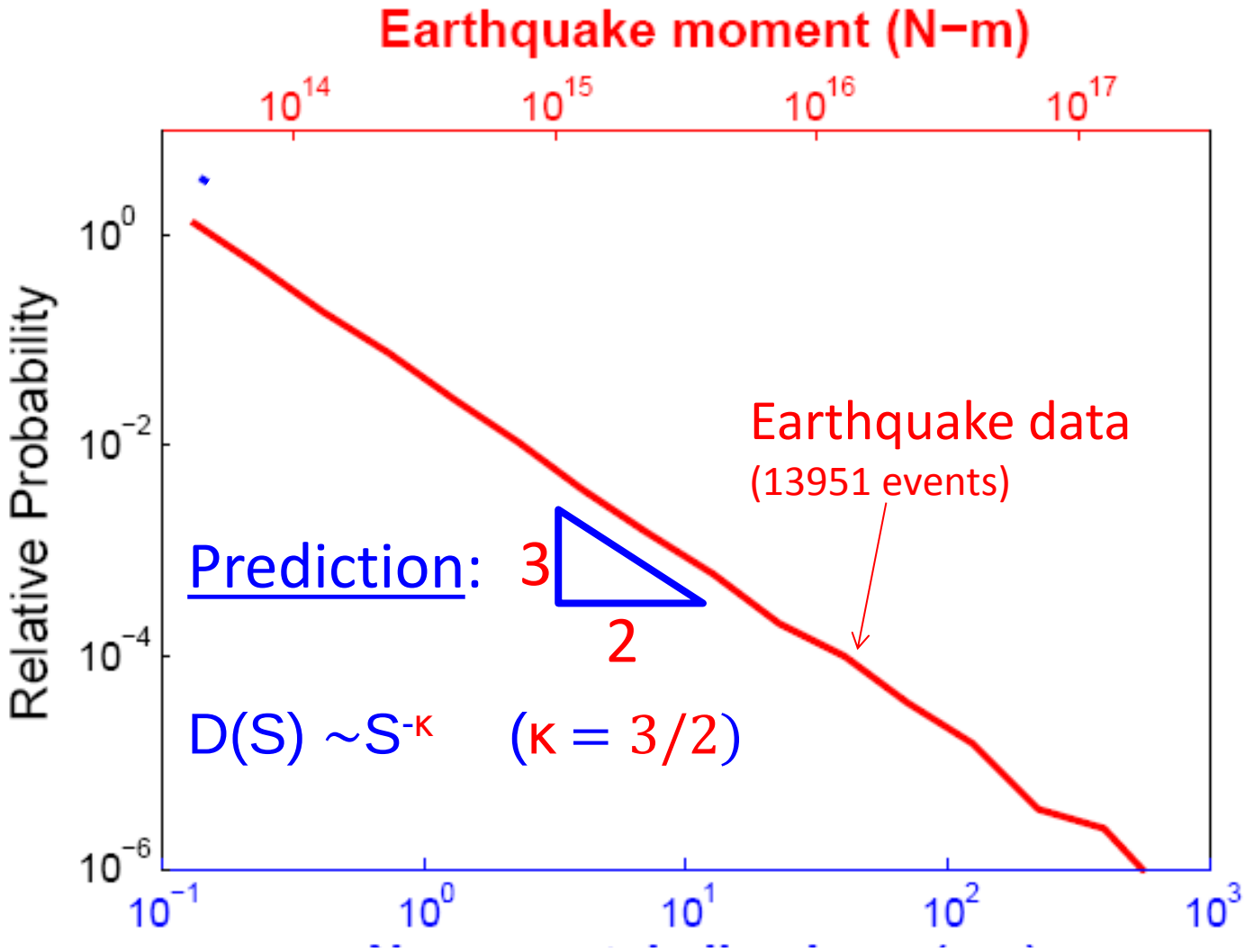
Similar to Carlson, Langer's statistics

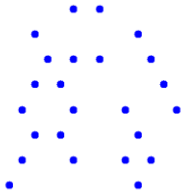
Simple Mean field Model Predictions Agree with full 3d Earthquake Simulations

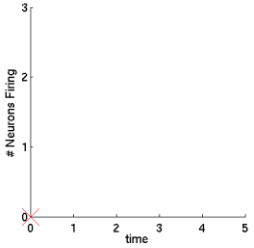
Fisher, KD, et al. PRL 1997; KD PRE 1998; Mehta, Ben-Zion, KD PRL 06; KD and Ben-Zion '08



Model predicts scaling exponents of earthquake moment distributon



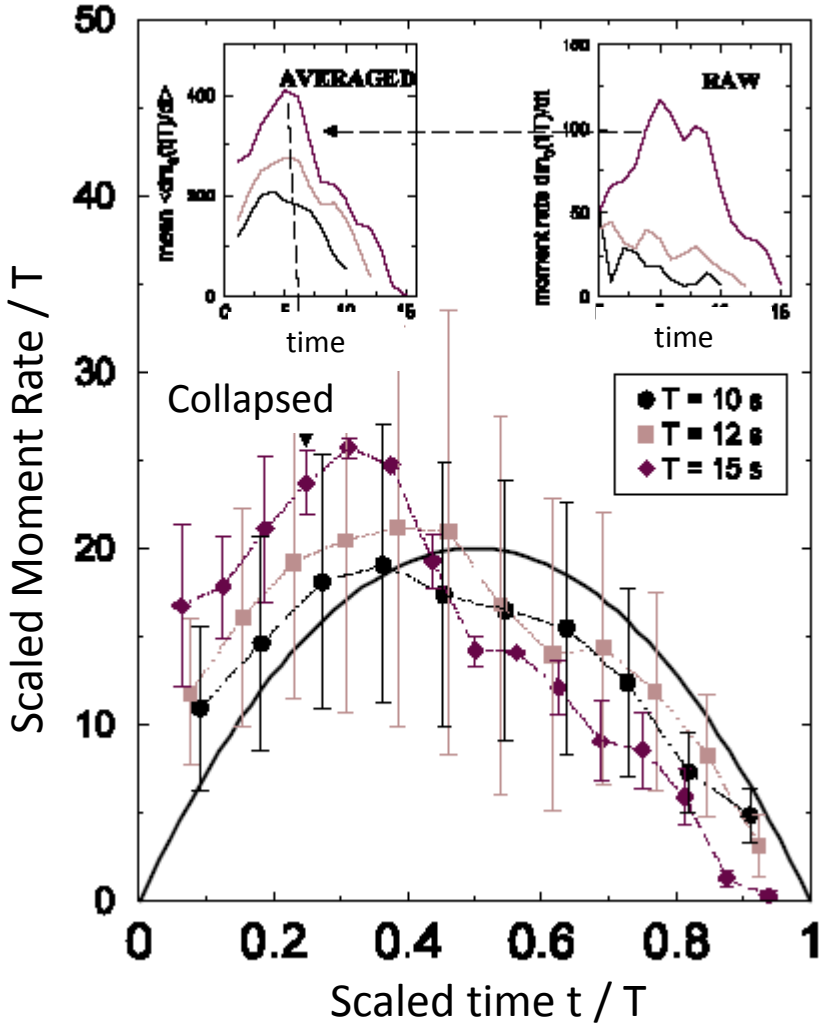


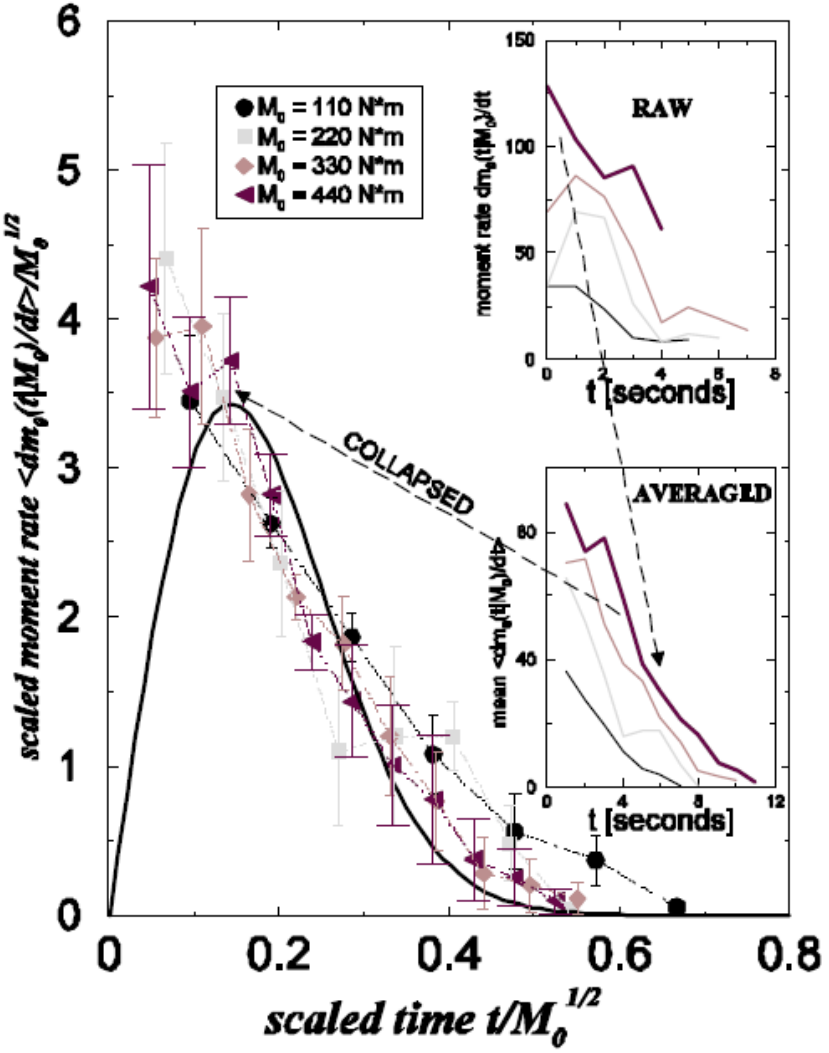


Earthquakes: Universal Scaling Functions

Data from Susan Bilek, see

Mehta, KD, Ben-Zion, PRE 2005





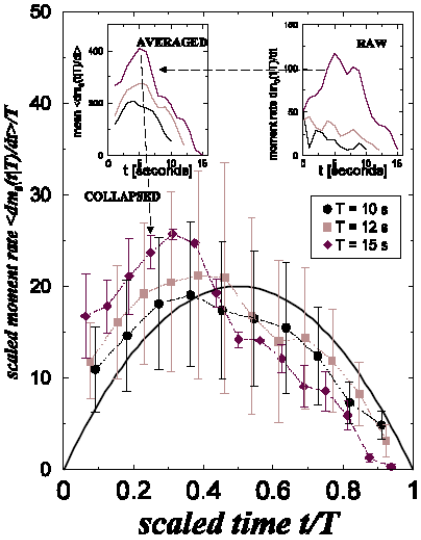
EXPERIMENTAL SCALING FUNCTION (MAGNETS)

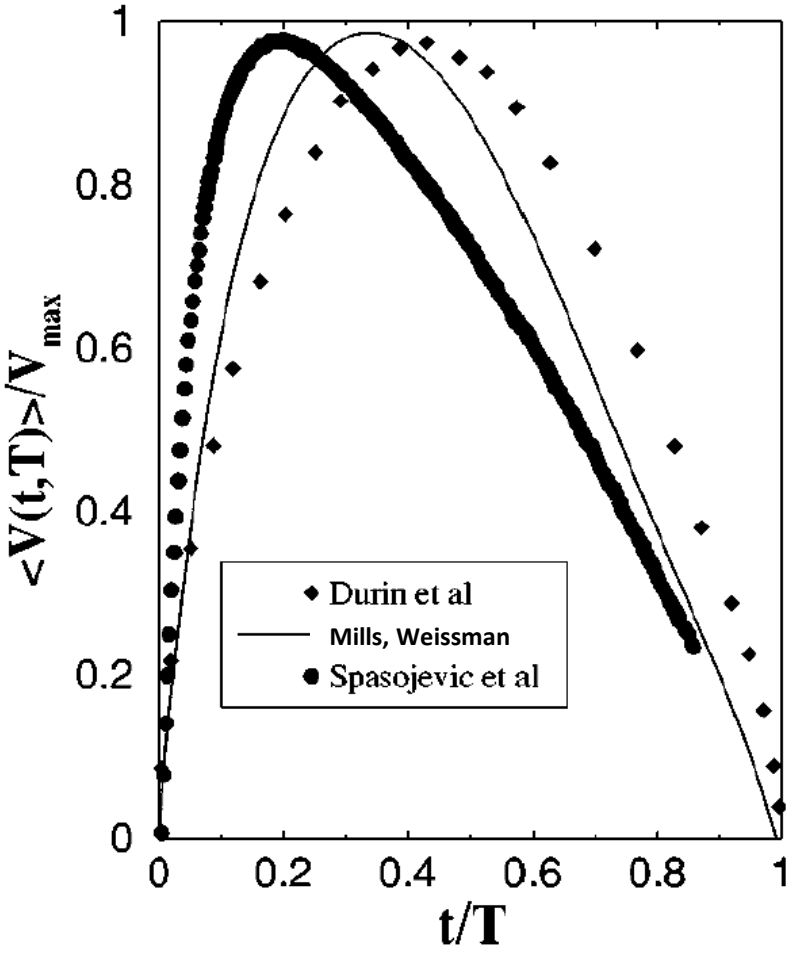
Asymmetric!?!

Sethna, Dahmen, Myers, Nature 2001

Mehta, Mills, Weissman, Dahmen PRE 2005, 2006

Like Earthquakes



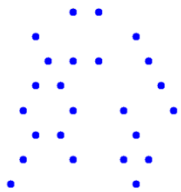


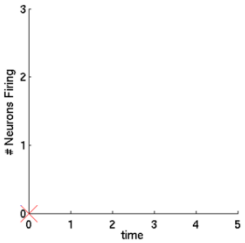
Eddy currents !

Zapperi, Durin et al. Nature Physics. 1, 46-49 (2005);

Dahmen, Nature Physics 1, 13-14 (2005)

Papanikolaou et al. Nature Physics (2011)





Some Open Questions:

1. Check scaling predictions: large earthquakes scale differently from small ones

2. Extract moment rate shapes for SMALL earthquakes (need high resolution)

3. Spatial correlations

4. Moment versus Duration, slipping Area, Energy etc. – assumptions in inverse problem solution

5. Temporal correlations, etc.