New Scaling in an Old Earthquake Model

C. A. Serino and W. Klein

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10 October 2009

Empirical Scaling

$$N_{GR}\left(M_0 > m\right) = A\, m^{-b}$$

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- Gutenberg & Richter observe the now-famous relation [Gutenberg and Richter, *Ann. Geophys.* **9,** 1 (1956)]:

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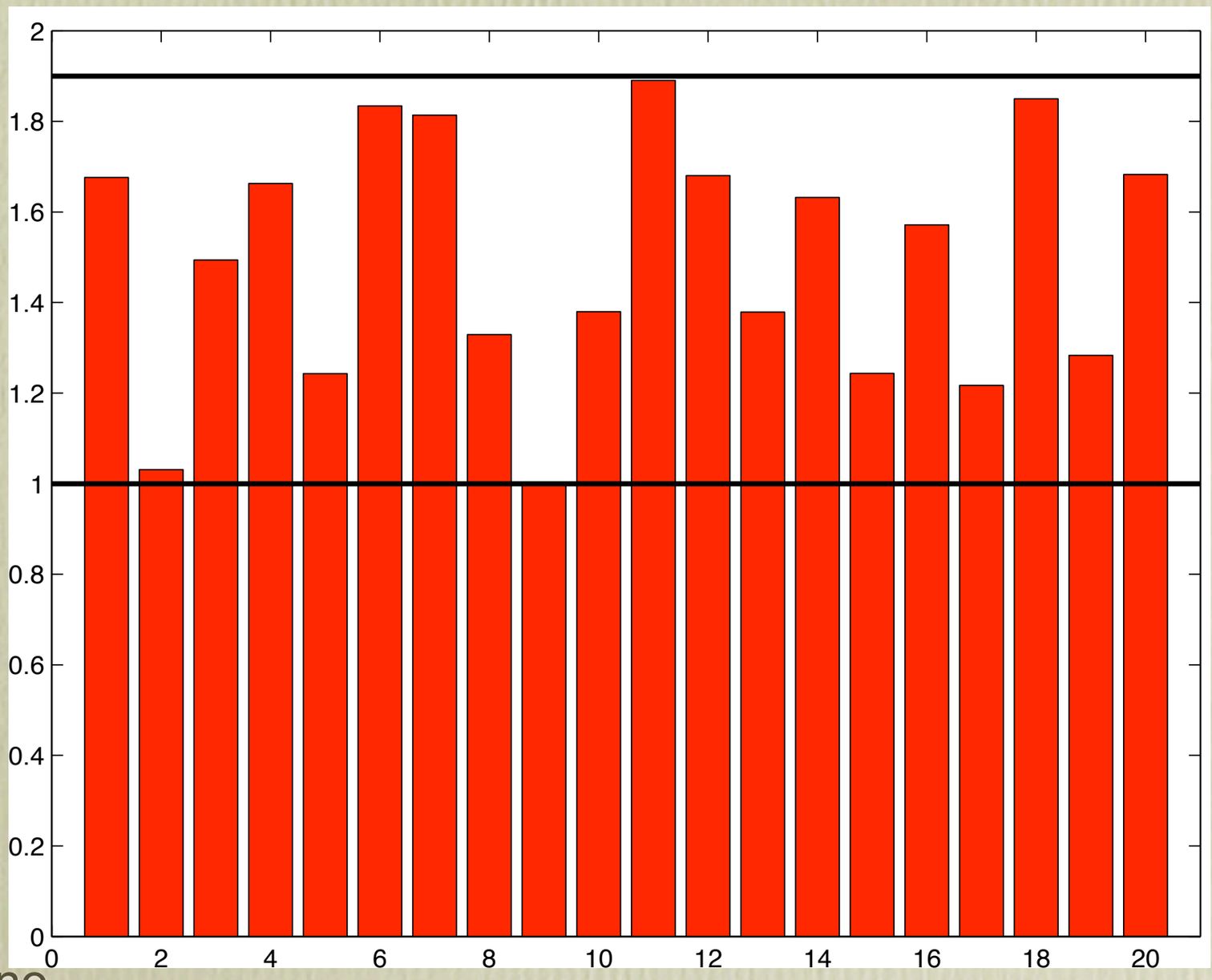
- Scaling occurs over *fault systems*, not single faults and b is determined from a *cumulative* distribution.

- Typical b-values lie in $0.8 \leq b \leq 1.2$ but can vary outside this region [Frohlich and Davis, *J. Geophys. Res.* **98,** 631-644 (1993)].

OFC Model

- Olami-Feder-Christensen (OFC) cellular automaton earthquake model. [Olami *et al*. *Phys. Rev. Lett.* **68**, 1244 (1988)



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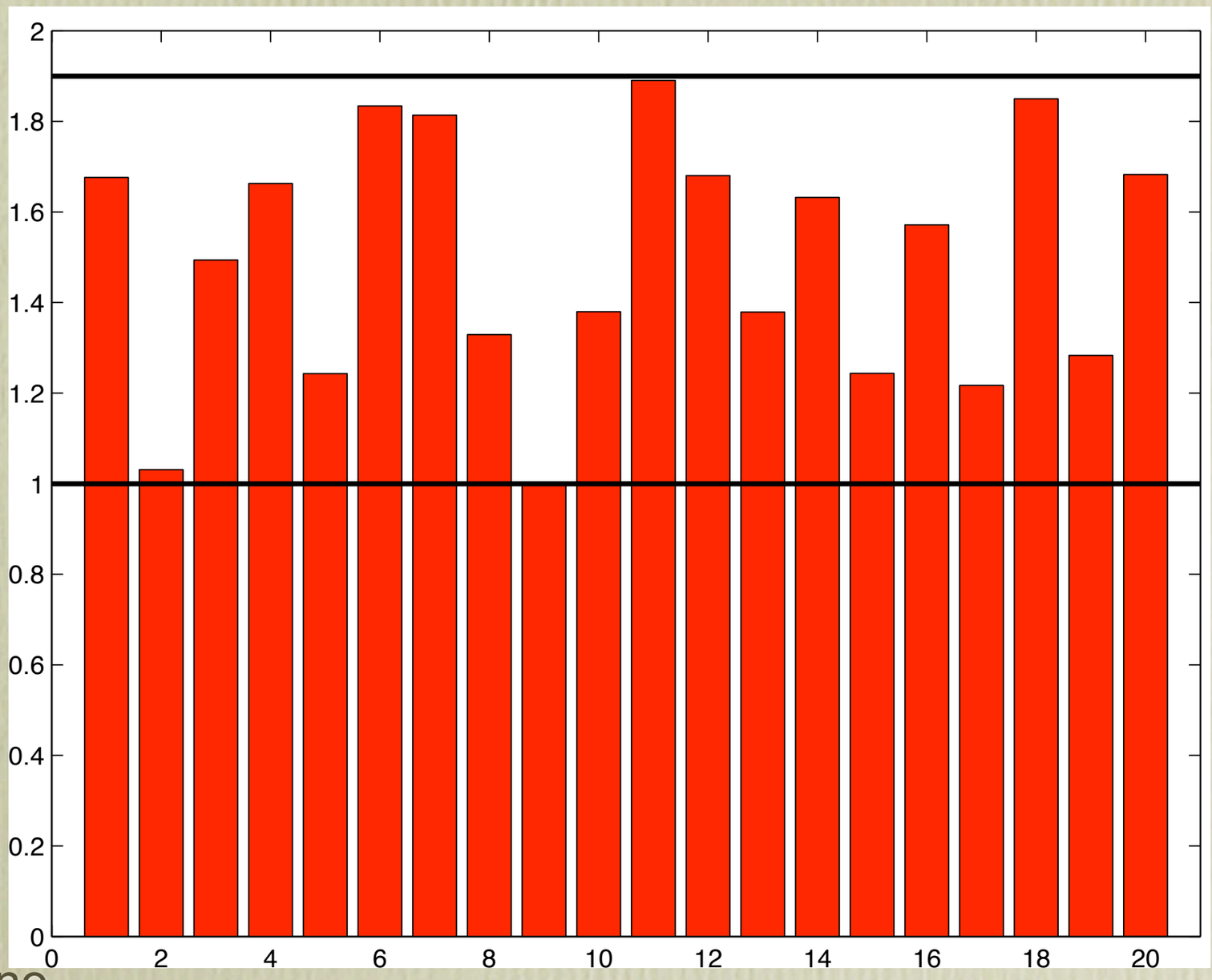

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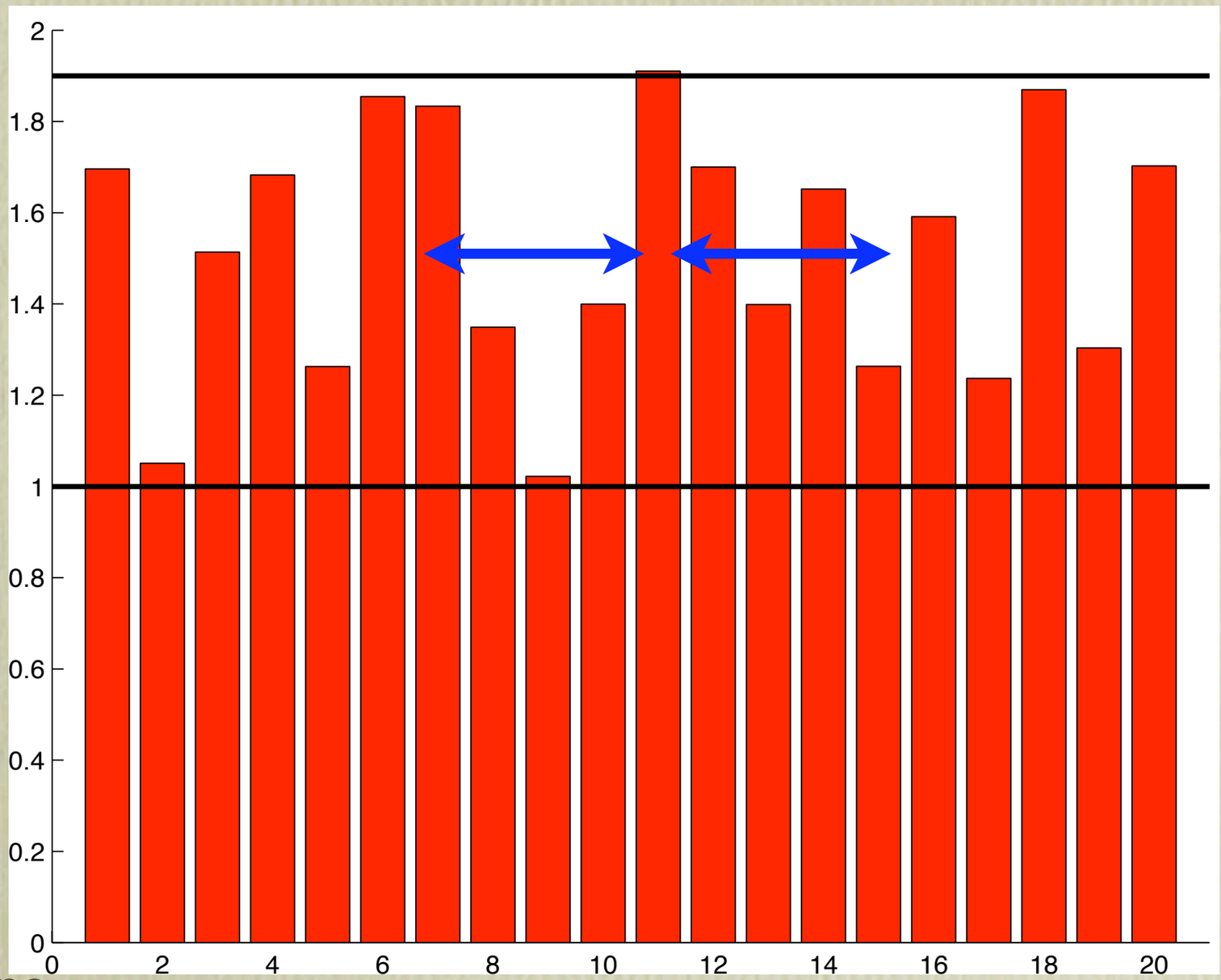

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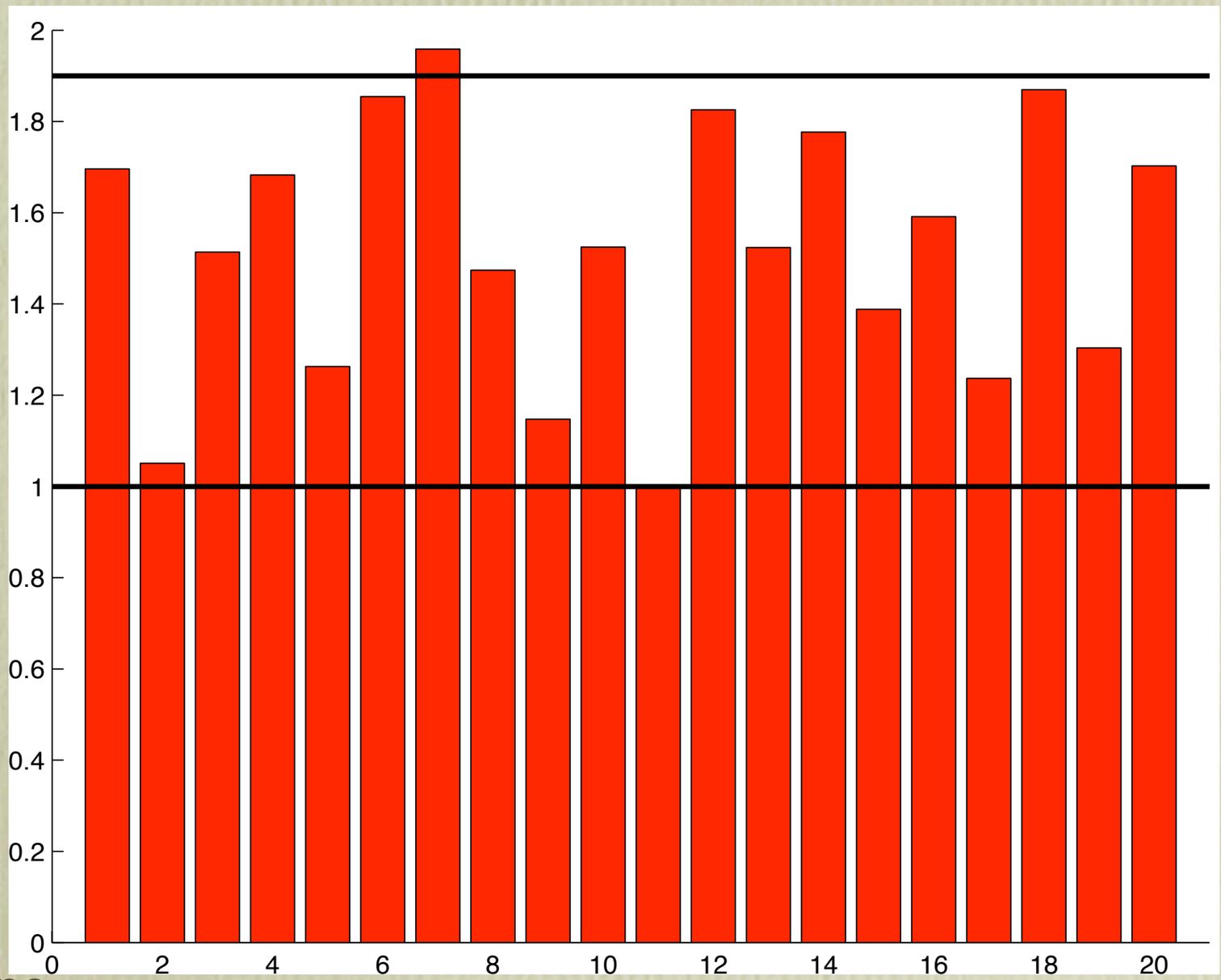

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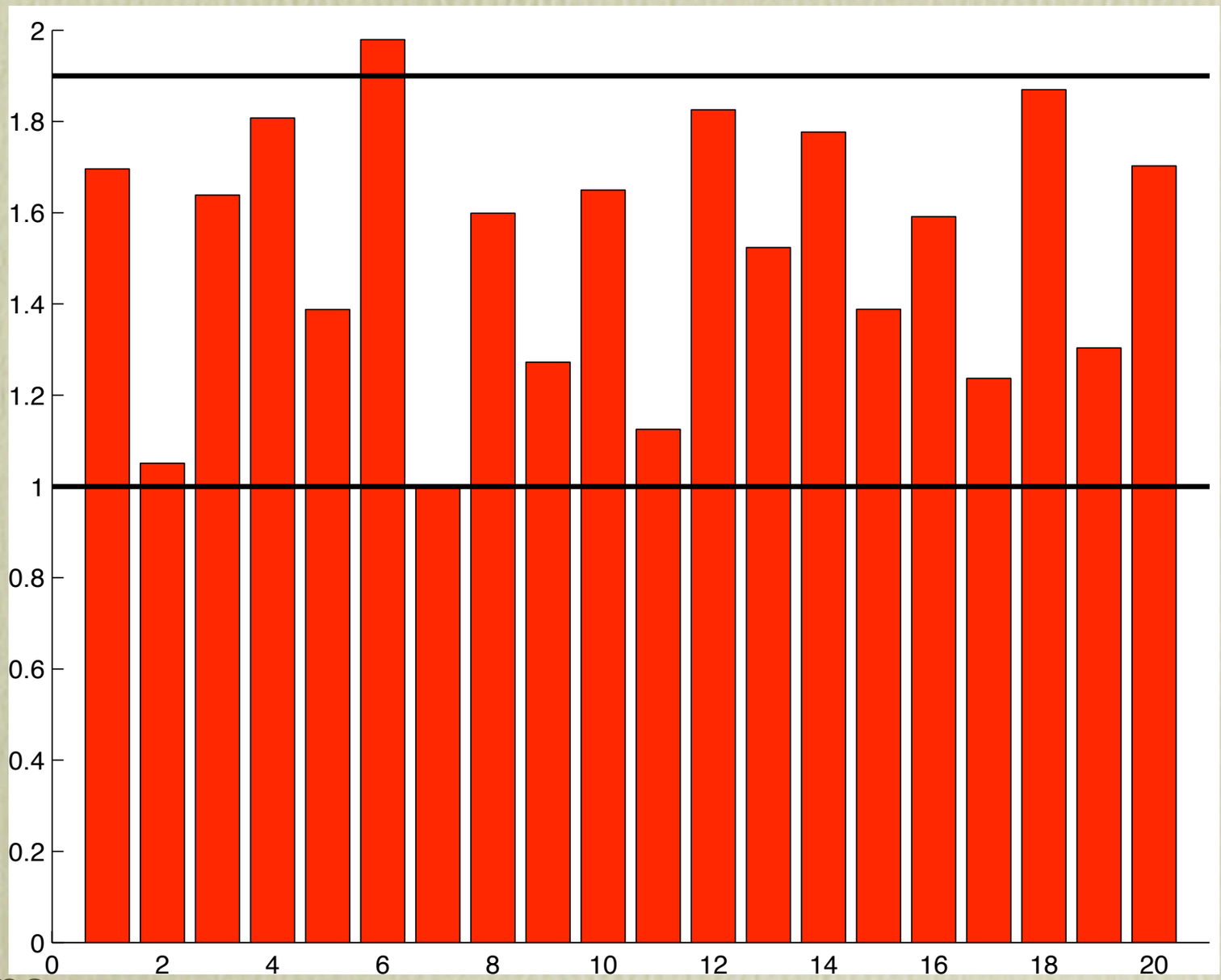

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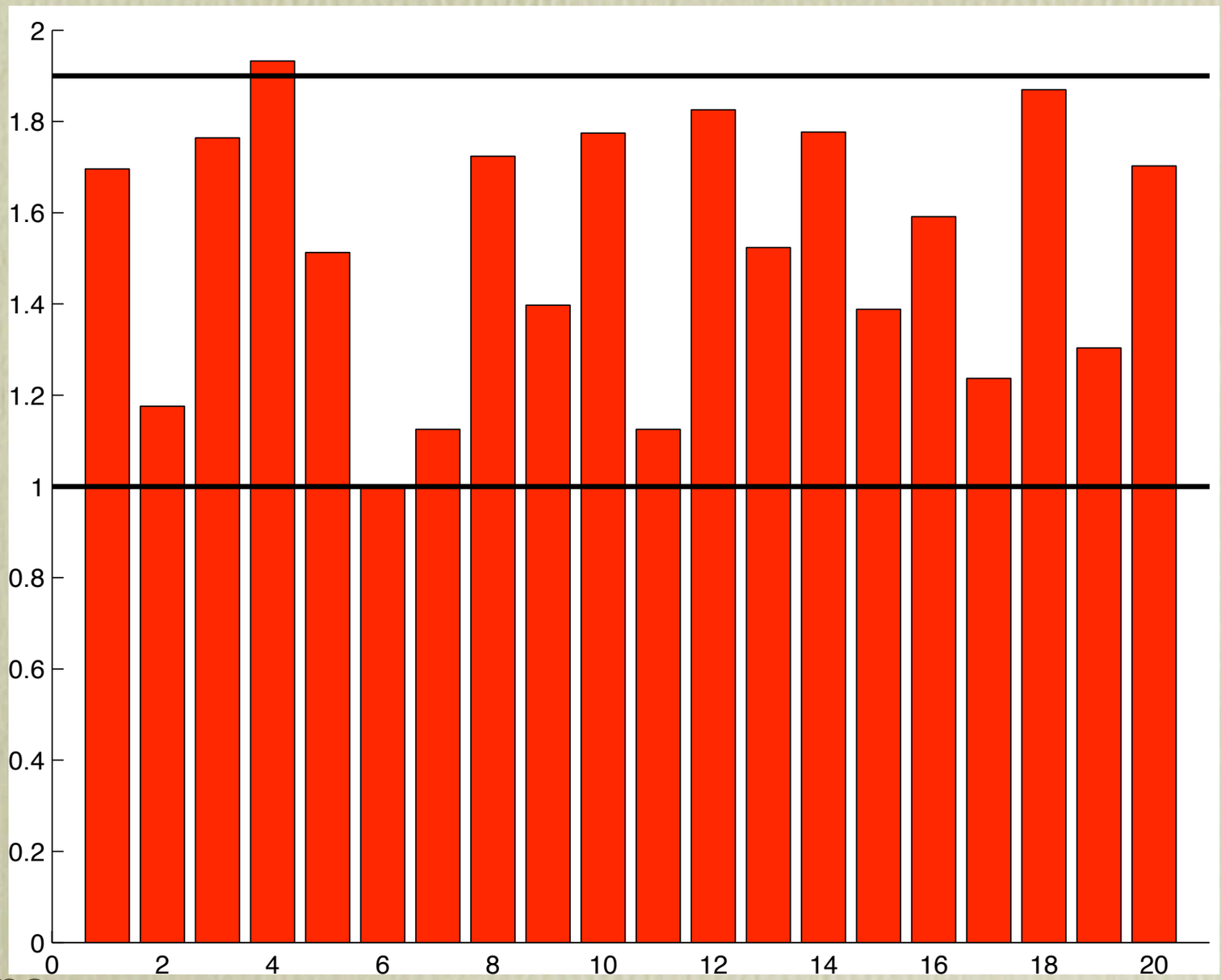

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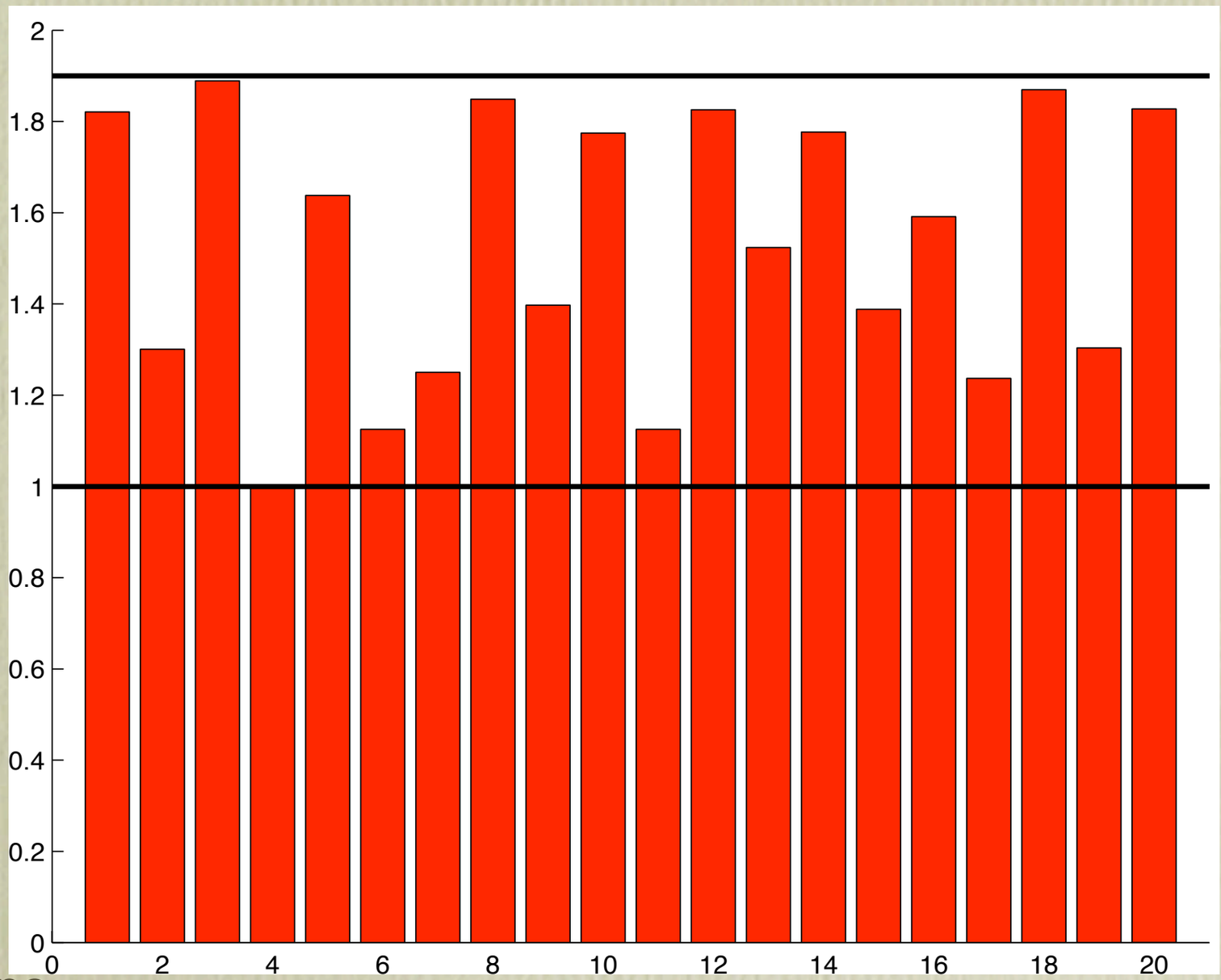

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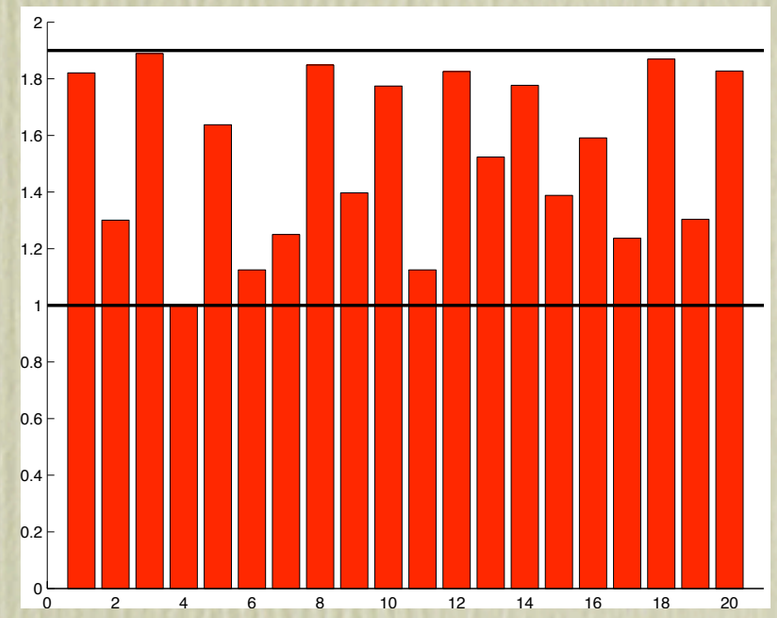

- These dynamics yield "cluster scaling" $N(s) \propto s^{-\tau}$ with $\tau = 3/2$ where $b = \tau - 1$.

Introduce Damage

- We can "freeze in" a certain fraction of damaged sites, $1-\phi$, that cannot receive stress from their neighbors.

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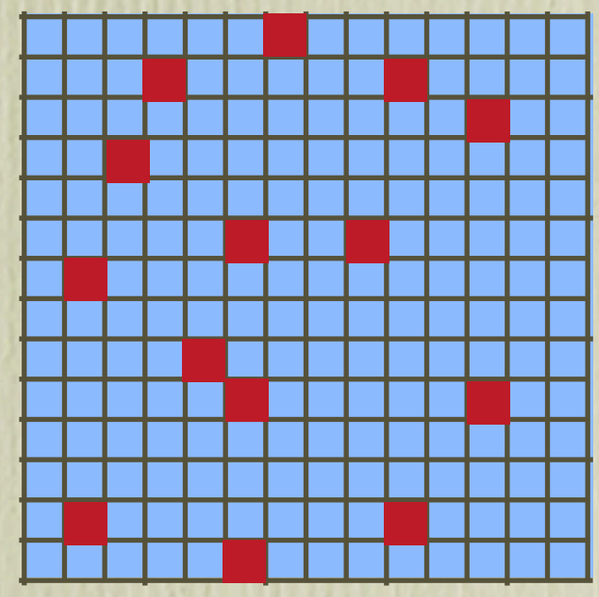

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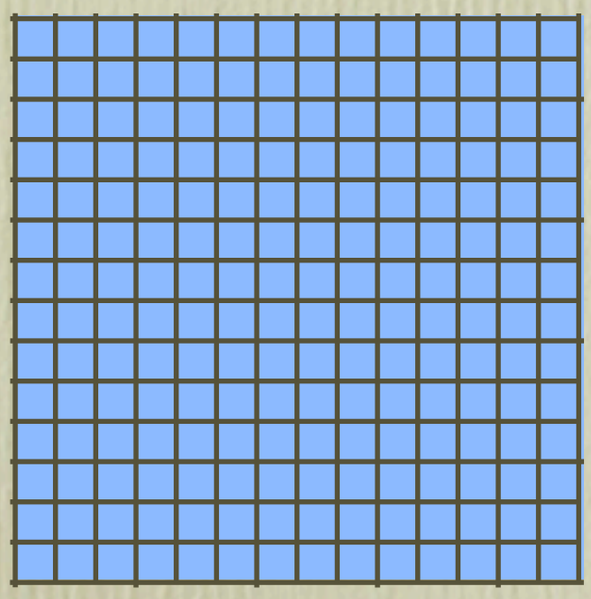
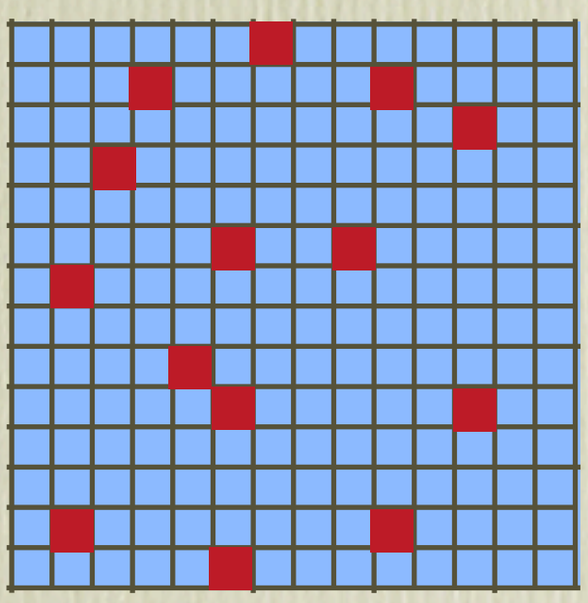
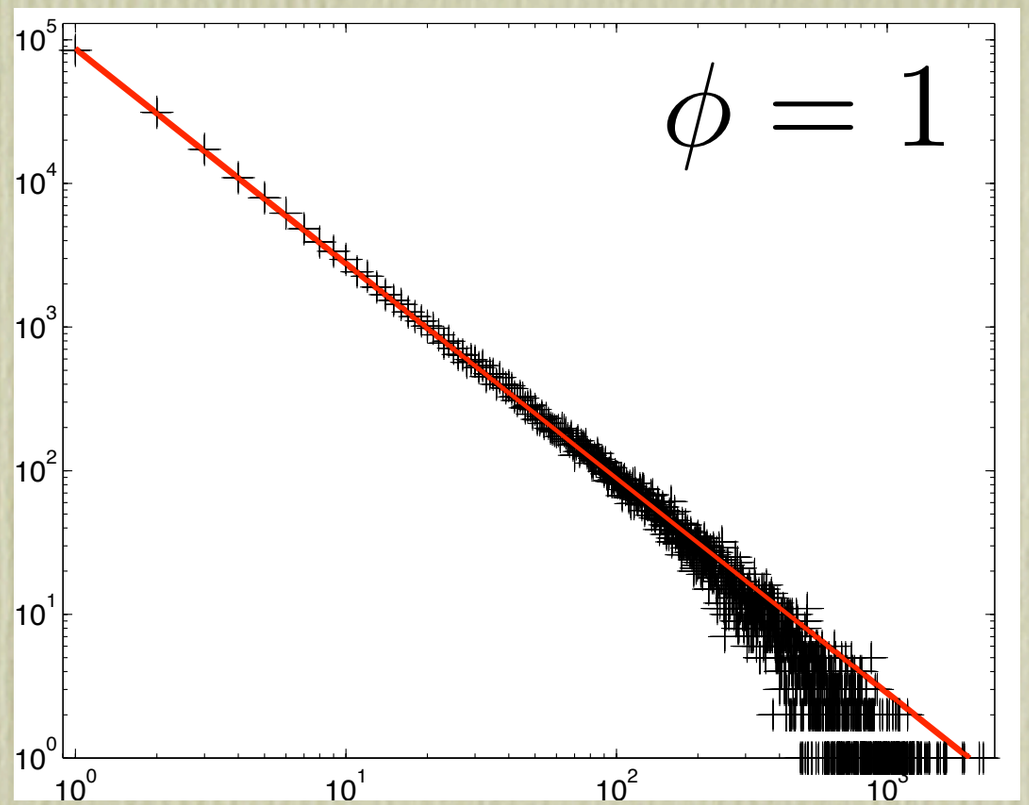
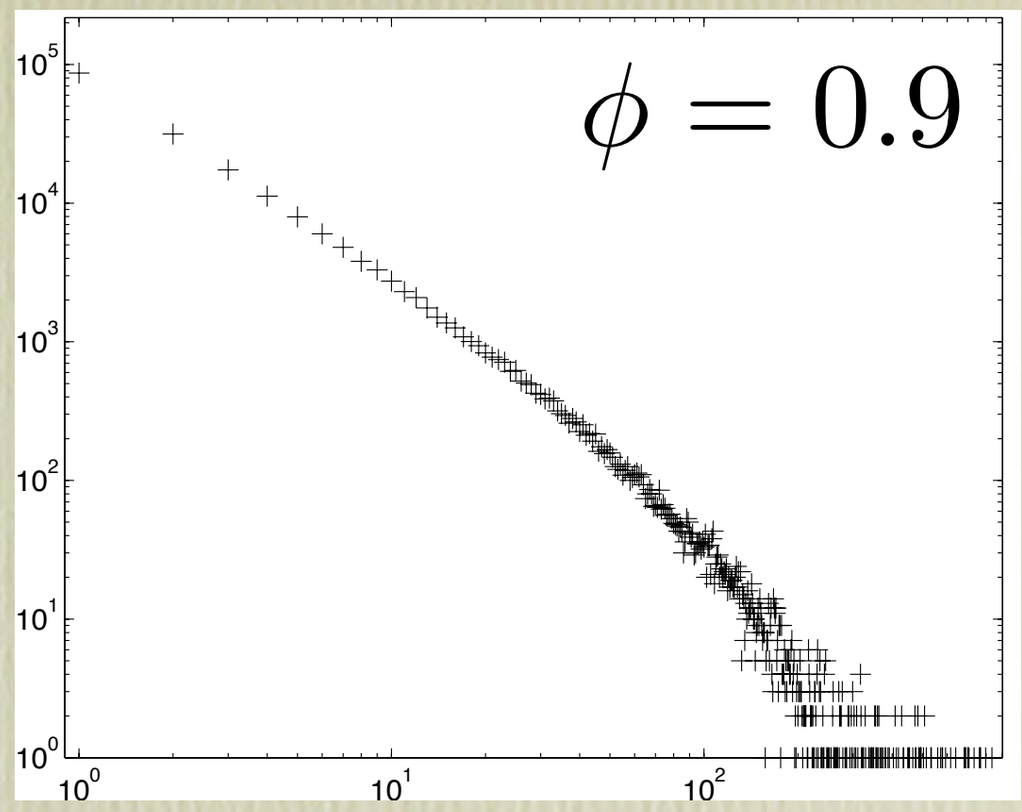
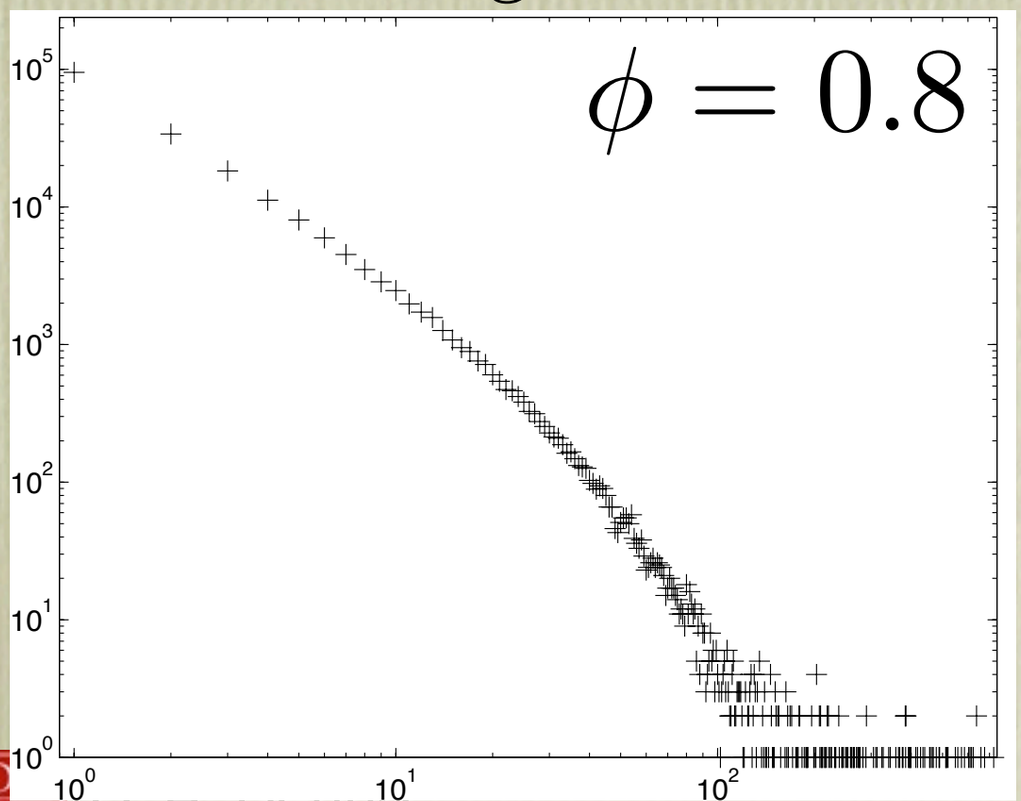


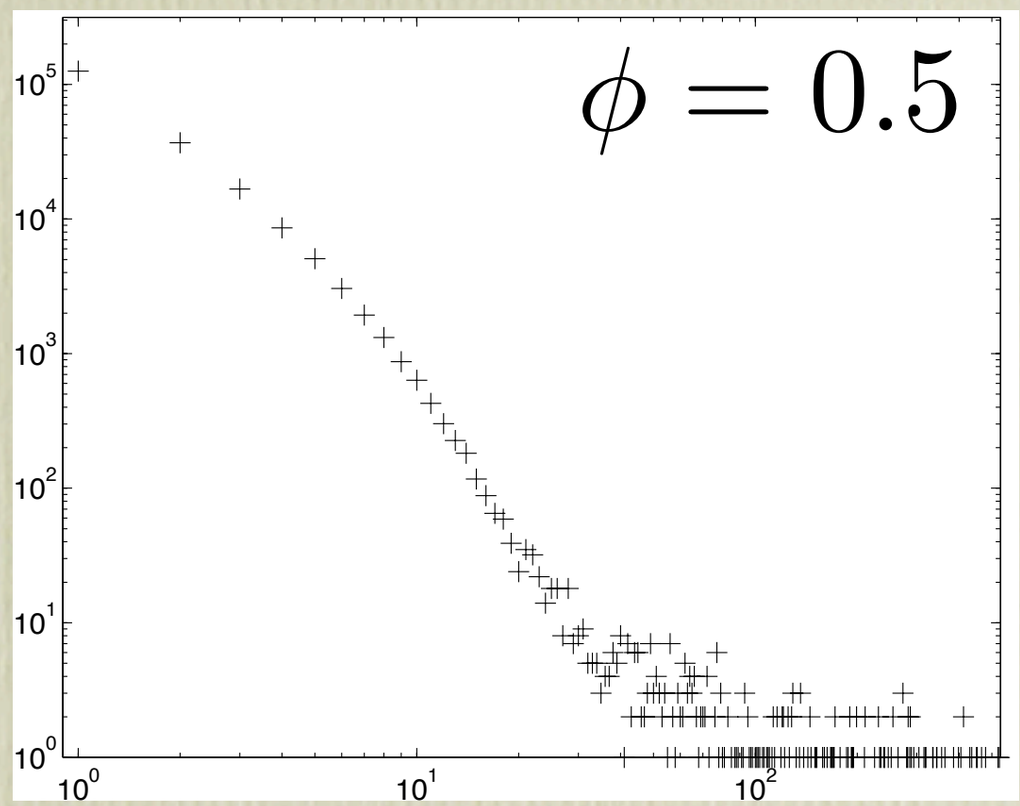


Reduced Scaling Regime









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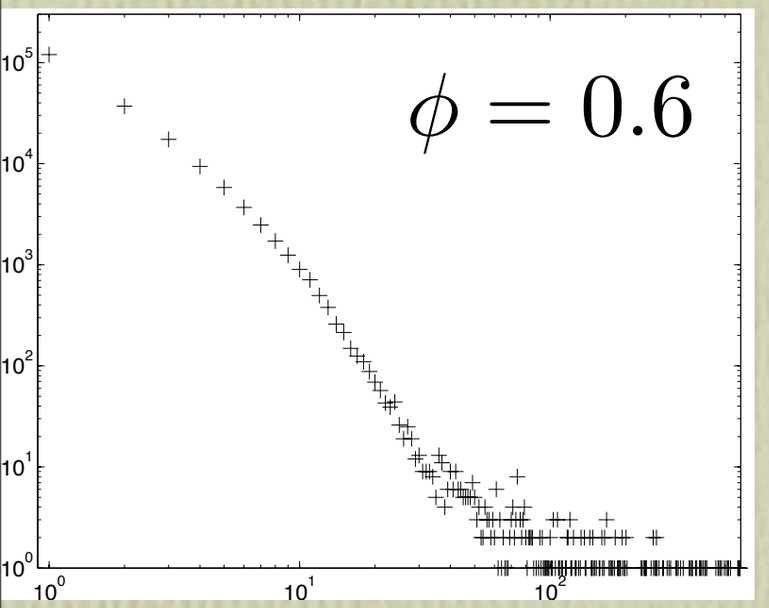
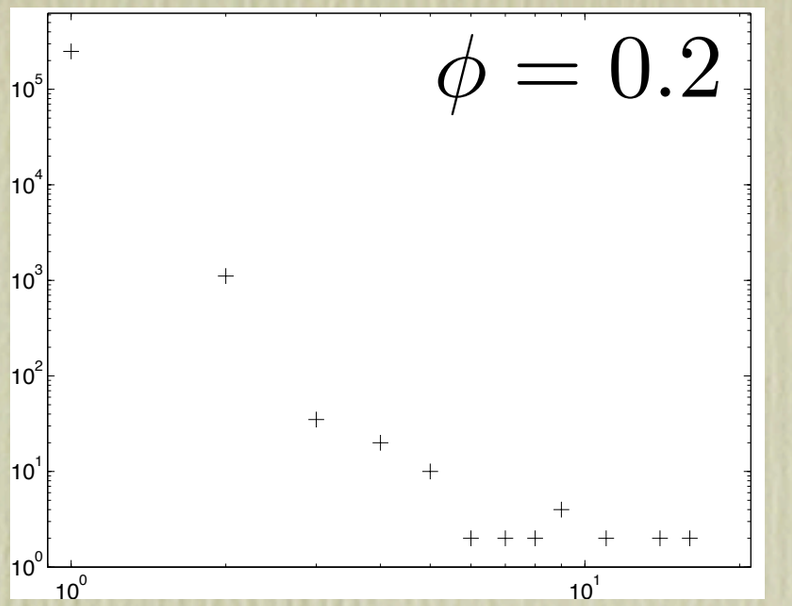
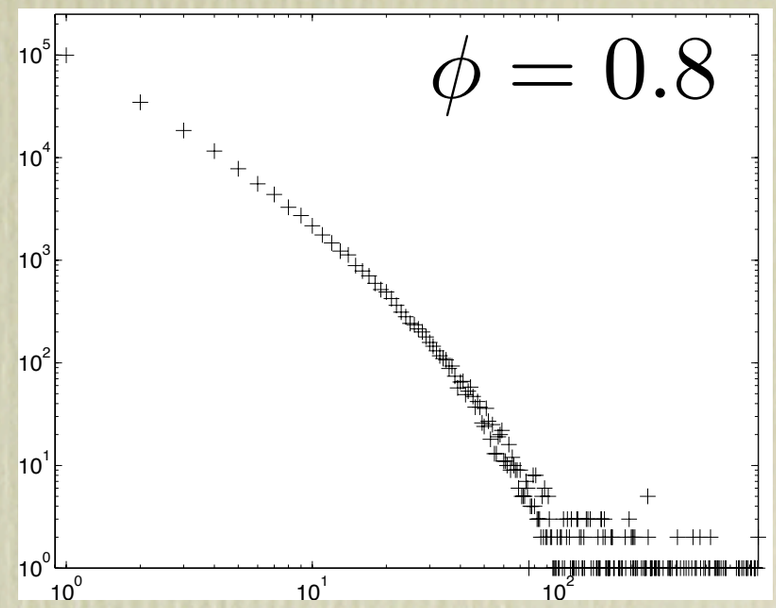
$\phi = 0.1$

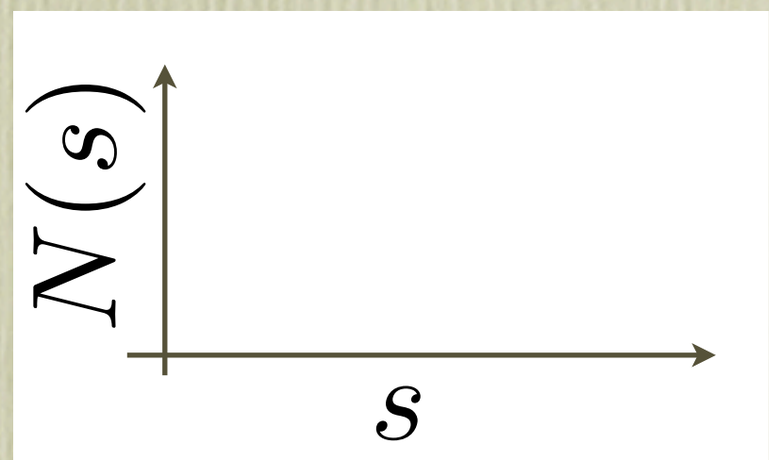


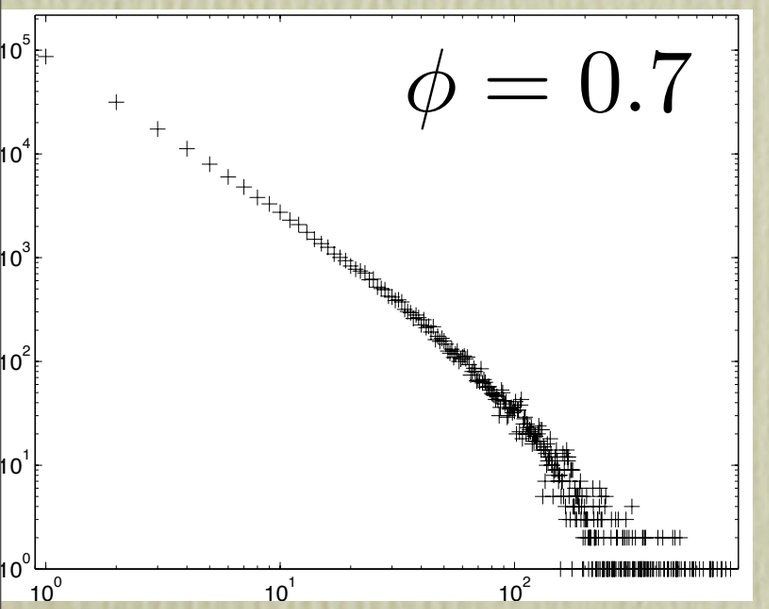
$\phi = 0.2$



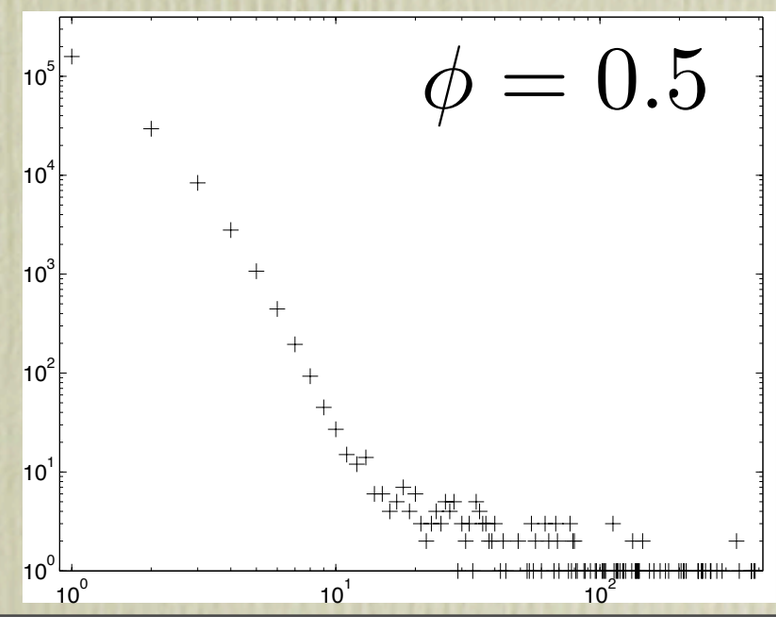
$\phi = 0.3$

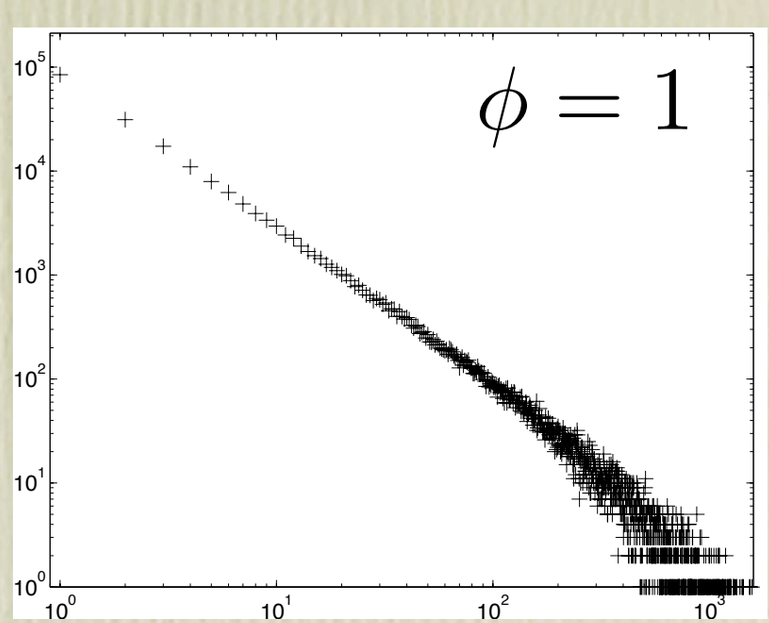






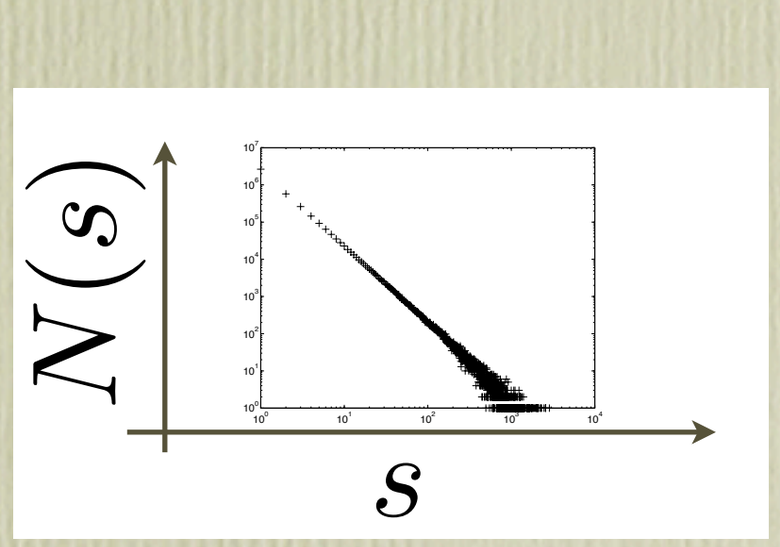
$\phi = 0.5$



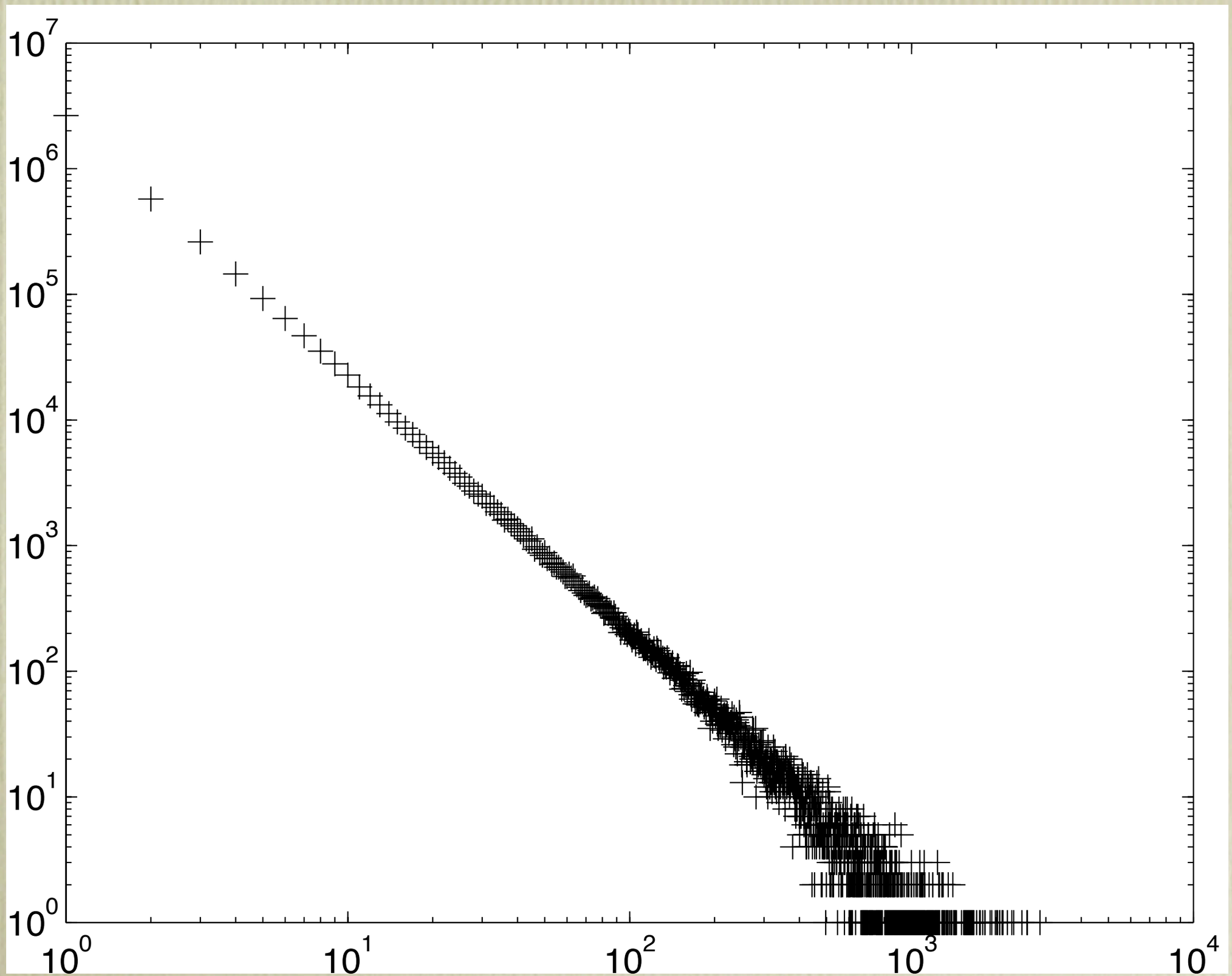


$\phi = 0.4$

$\phi = 0.9$


N(s)
s
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
10^4

"New" Scaling



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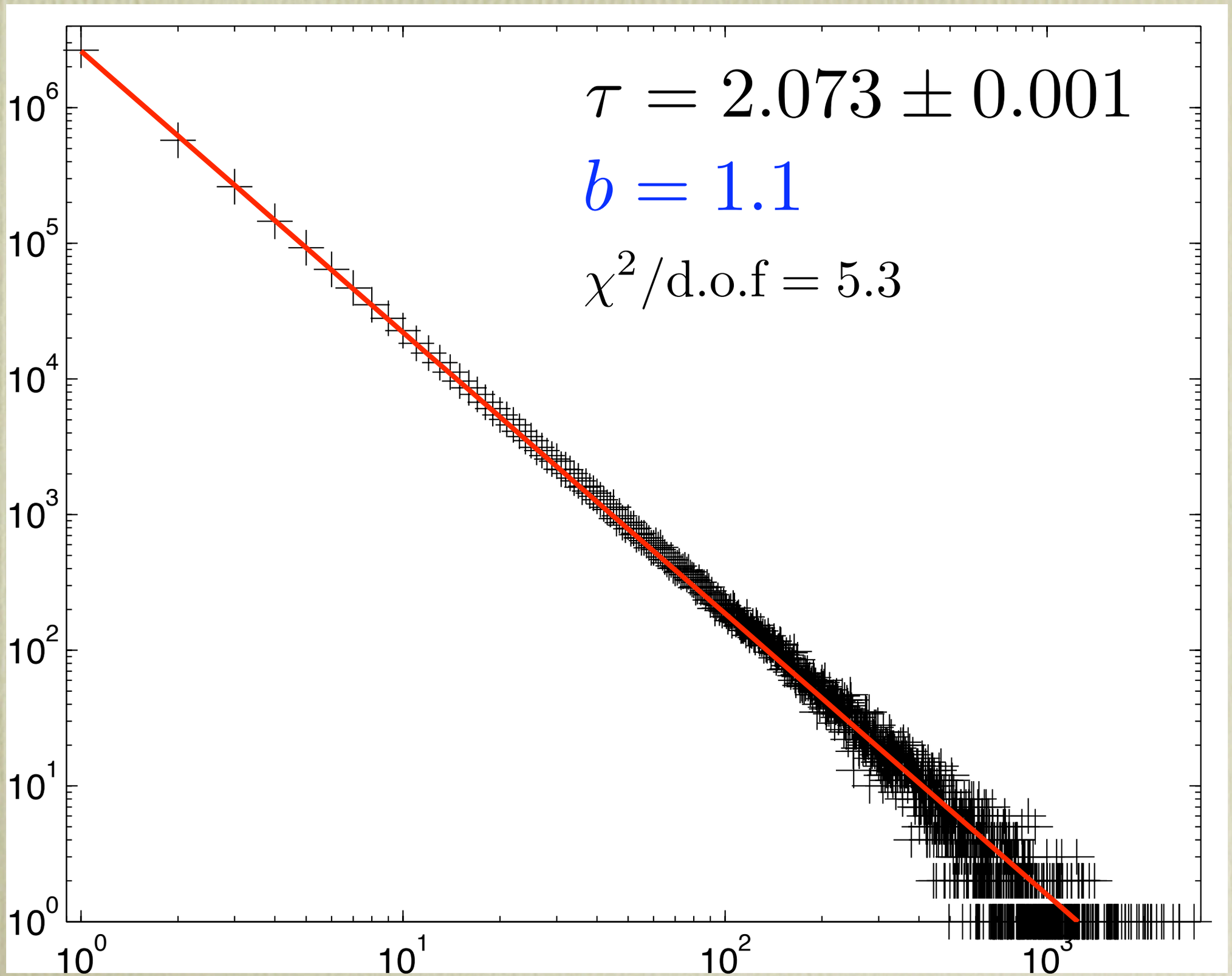
$\tau = 2.073 \pm 0.001$
$b = 1.1$
$\chi^2/\text{d.o.f} = 5.3$
$N(s)$
s
10^0
10^1
10^2
10^3
10^4
10^5
10^6

Summary

- Seismologists have observed that the frequency of earthquakes scales as a power-law with respect to the size or magnitude of the event.
- Empirical evidence suggests that most exponents, b, lie in a small window about $b = 1$.
- The OFC model gives rise to scaling with $b = 0.5$.
- The modified OFC model with damage produces new scaling with exponent $b = 1$.

Thank You

Further information:

C. A. Serino *et. al.* arXiv:0905.3860 [cond-mat.stat-mech]