# Large variance and fat tail of damage by natural disaster

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# Second International Conference on Vulnerability and Risk Analysis and Management (ICVRAM2014) & Sixth International Symposium on Uncertainty Modelling and Analysis (ISUMA2014)

13th - 16th July 2014, University of Liverpool, UK



## Welcome to ASCE-ICVRAM-ISUMA 2014

INSTITUTE FOR RISK AND UNCERTAINTY

UNIVERSITY OF LIVERPOOL

*In collaboration with:*

ASCE | DISASTER RISK MANAGEMENT

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VIRTUAL ENGINEERING CENTRE

ASCE-ICVRAM-ISUMA provides a multi-disciplinary forum for the exchange of knowledge and expertise, in the Quantification, Mitigation and Management of Risk and Uncertainty, and in Decision Making.

The event is aimed at specialised and synergetic developments in both theory and practice.

This joint conference is being organised by the Institute for Risk & Uncertainty and in collaboration with the ASCE Council on Disaster Risk Management, the Environmental Change Institute (University of Oxford) and the Virtual Engineering Centre.

The proceedings of the conference are now available: ASCE library.

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**ICVRAM2014 Conference timeline:**

**30th November 2013:**
ASCE Full paper submission

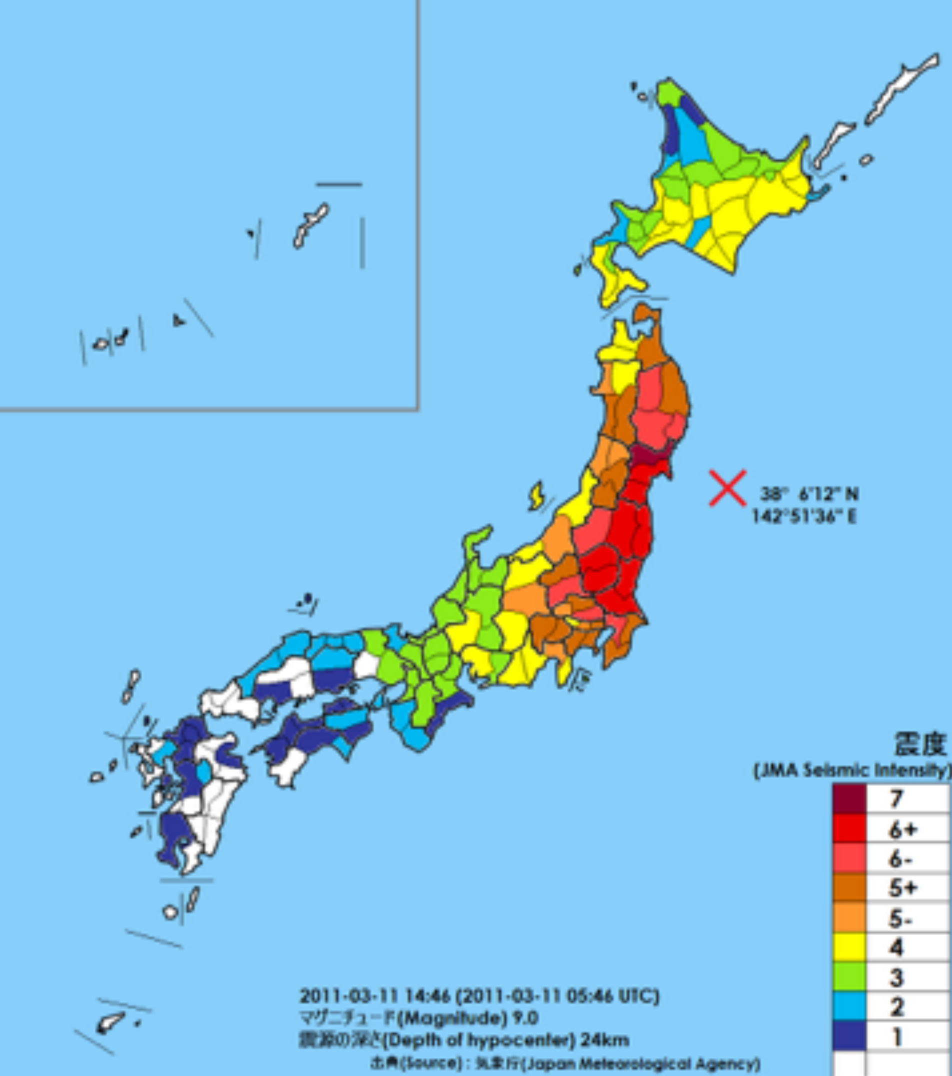
**15th February 2014:**
Deposit and/or early bird registration deadline

**1st of May 2014:**
Full paper submission (not included in the ASCE proceedings)

**1st June 2014:**
Scientific programme

**13th-16th July 2014:**
Conference

View photos of the ASCE-ICVRAM-ISUMA 2014

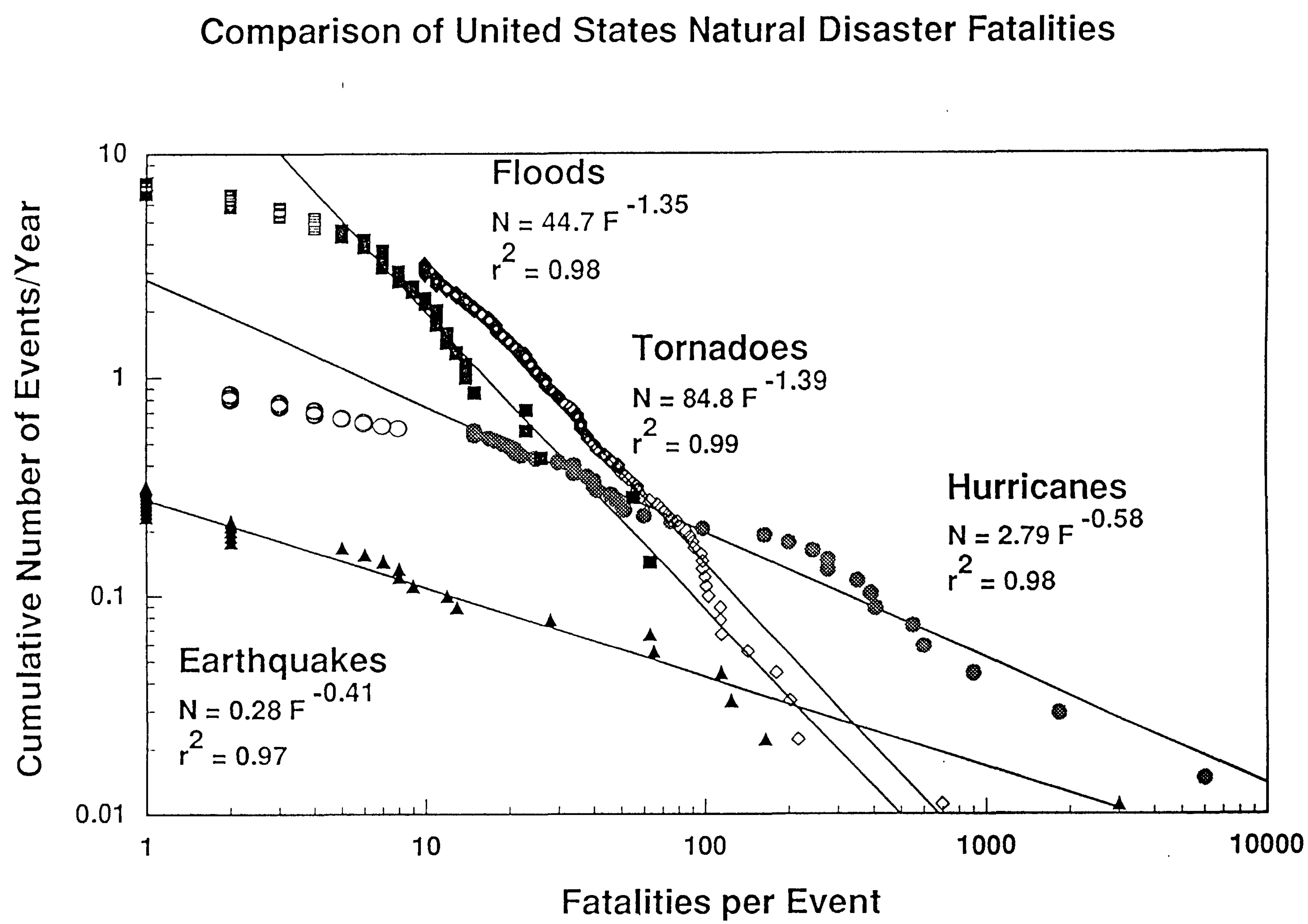



**Japan, March 11, 2011**

How much can we spend for disasters with low probability but huge damage?

Extreme events occur!

# Statistics of damage




Nishenko & Barton, USGS (1995)

# Statistics of damage

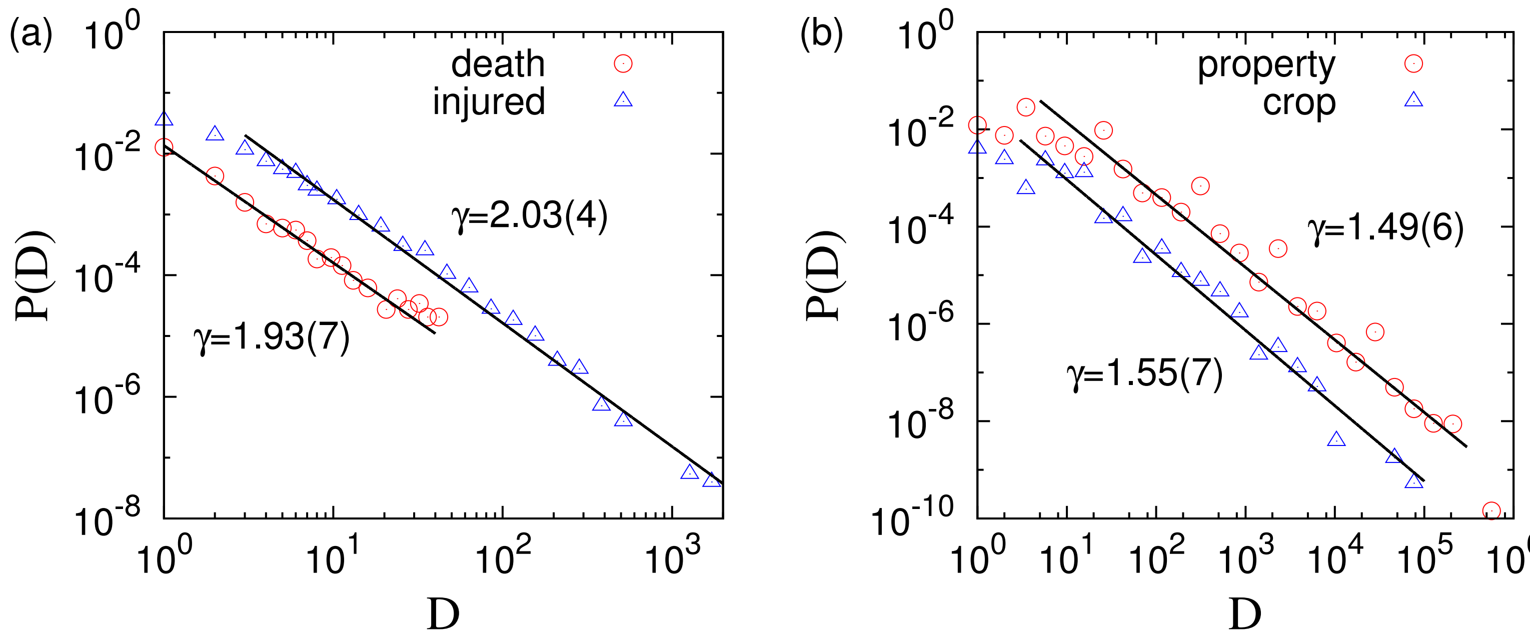



**Figure 4. Empirical damage distributions by tornadoes in the United States from 1970 to 2011 and estimated power-law exponents (a) for the numbers of death and injured and (b) for property and crop damages estimated in US dollars.**

# Extreme events occur!

$$\begin{aligned} \text{damage} &= \text{natural disaster} \\ &\times \text{population/property} \\ &\times \text{vulnerability} \end{aligned}$$

Stromberg, J. Econ. Perspect. (2007)

# Assumption 1a

- Population/property is power-law distributed.

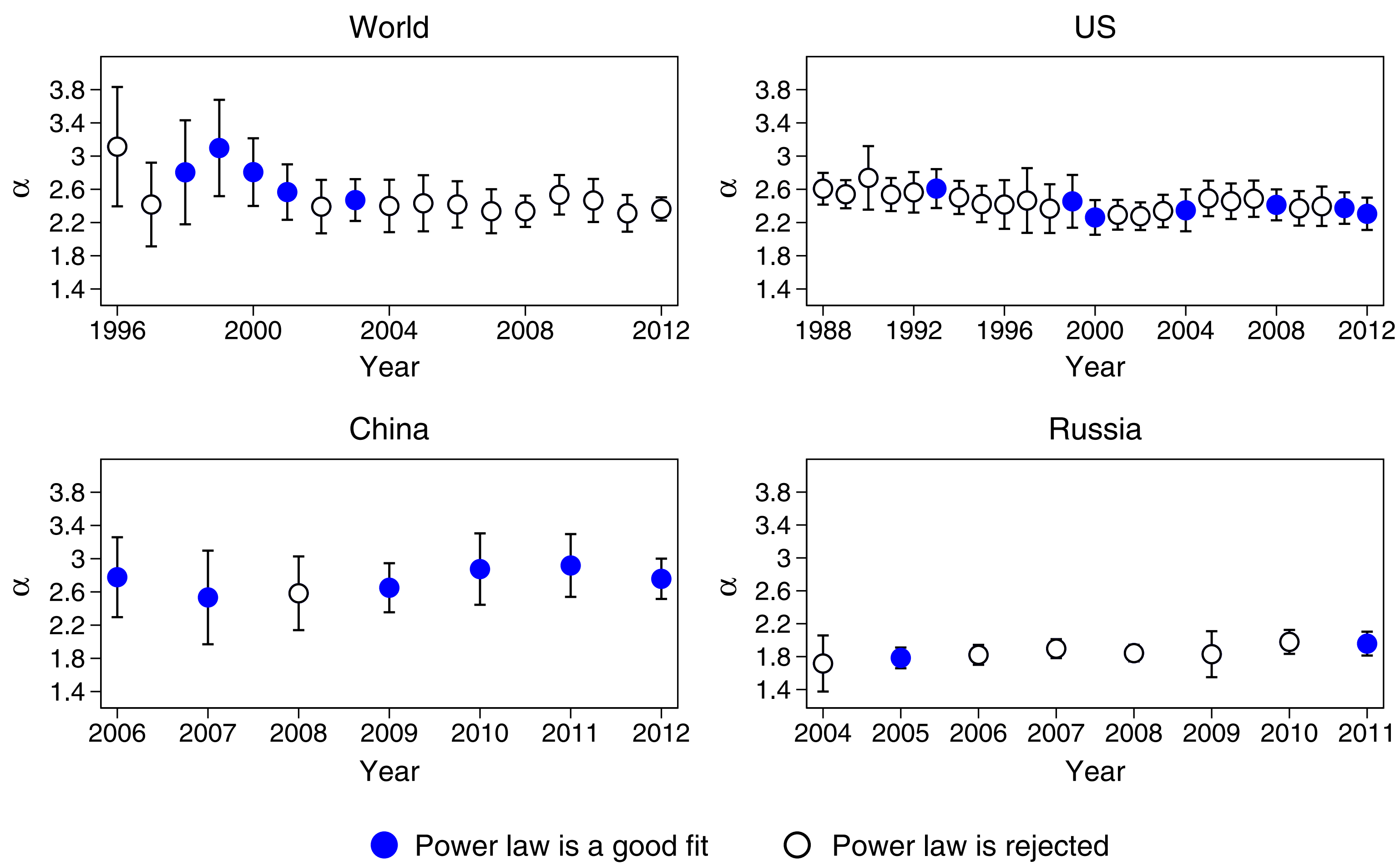



**Fig. 1.** Power-law exponents and goodness-of-fit tests for wealth data. *Note:* Vertical bars show 95% confidence intervals.

Brzezinski, Physica A (2007)

# Assumption 1b

- Population/property is spatially correlated.

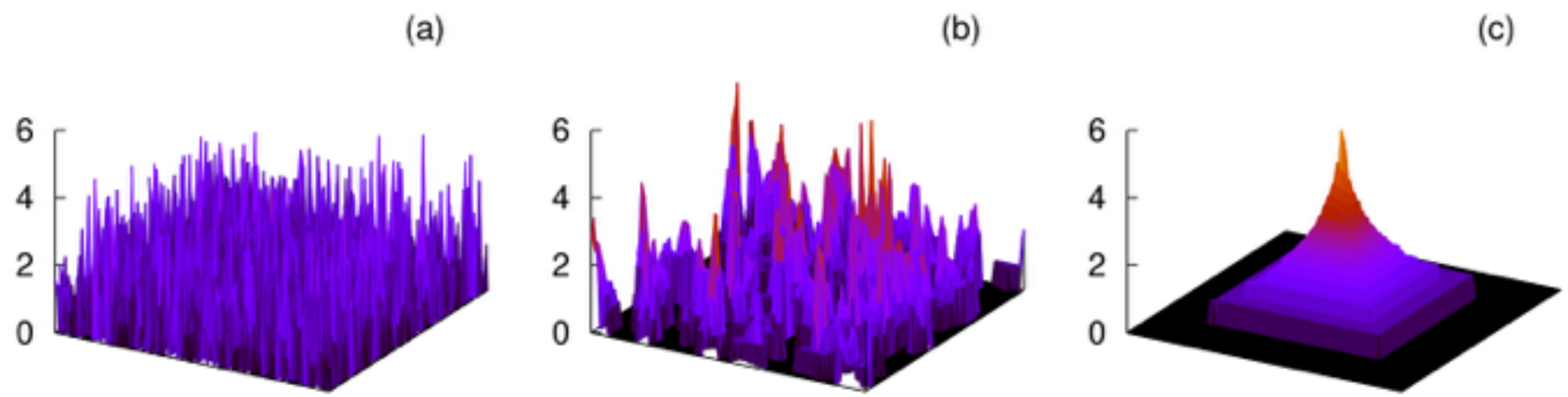
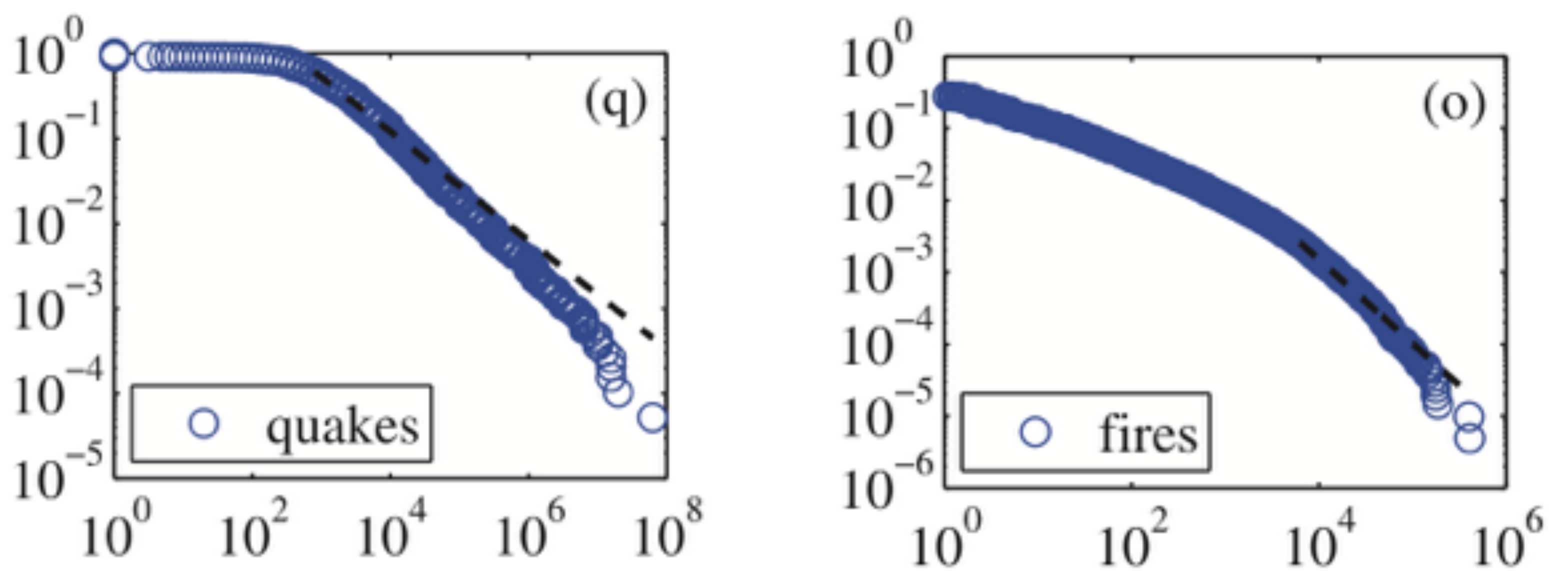



**Figure 1. (a) Random, (b) correlated, and (c) concentrated configurations of values on a two-dimensional lattice of size $100 \times 100$, where the probability density function of value $v$ follows a power-law as $P(v) \sim v^{-\alpha}$ with $\alpha = 2.5$. The height at each site represents a logarithm of the value.**

# Assumption 2

- Natural disaster is power-law distributed.




Clauset *et al.*, SIAM Rev. (2009)

# Assumption 3

- Vulnerability is constant.

# Question

- Population/property: power-law exponent **α**, spatial correlation **c**

- Natural disaster: power-law with exponent **β**

- Damage: power-law with exponent **γ**

$$\gamma(\alpha, \beta, c)?$$

# Model

- Each site on 2D lattice: a value v from $P(v) \sim v^{-\alpha}$
- Spatial correlation **c** adjusted by simulated annealing: $0 \leq$ **c** $\leq 1$
- A tornado at a random site moves in a random direction on a line with length l from $P(l) \sim l^{-\beta}$
- A damage is the sum of values on the line:

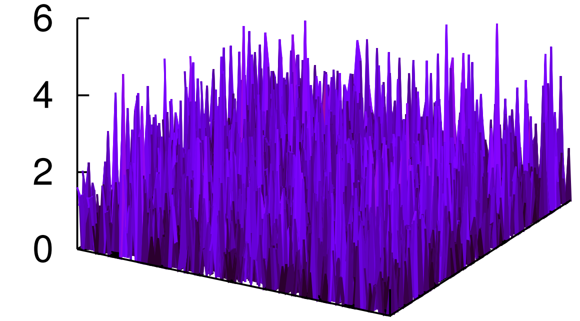
$$D(i_0, j_0, l) = A \sum_{i=i_0}^{i_0+l-1} v_{i,j_0}$$

# Random config.

- Totally uncorrelated case (c=0):

$$D = \sum_{n=1}^{l} v_n \qquad \begin{array}{c} P(v) \sim v^{-\alpha} \\ P(l) \sim l^{-\beta} \end{array}$$

Jo *et al.*, PRE (2013)



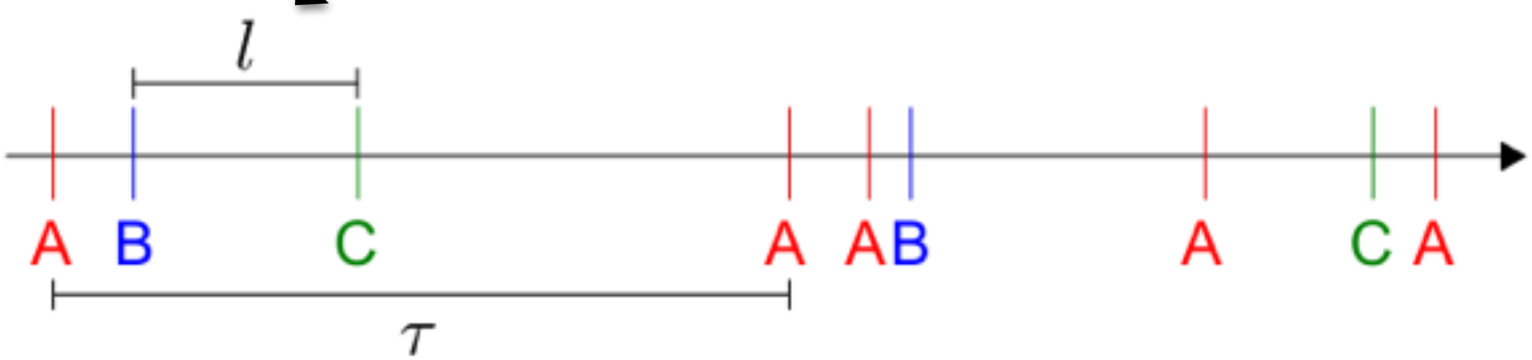

$$\begin{aligned} P(D) &\sim D^{-\alpha} + D^{-\beta} + D^{-(\alpha-1)(\beta-1)-1} \\ &\sim D^{-\gamma}, \end{aligned}$$

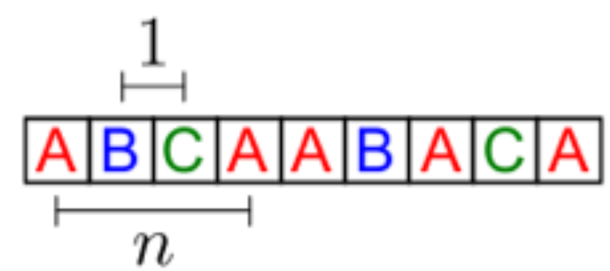
$$\gamma = \min\{(\alpha-1)(\beta-1)+1, \alpha, \beta\}$$

# Cf. Contextual bursts

$P(l) \sim l^{-\alpha}$

collective **real** inter-event time




contextual **real** inter-event time

$P(\tau) \sim \tau^{-\alpha'}$

contextual **ordinal** inter-event time

$P(n) \sim n^{-\beta}$

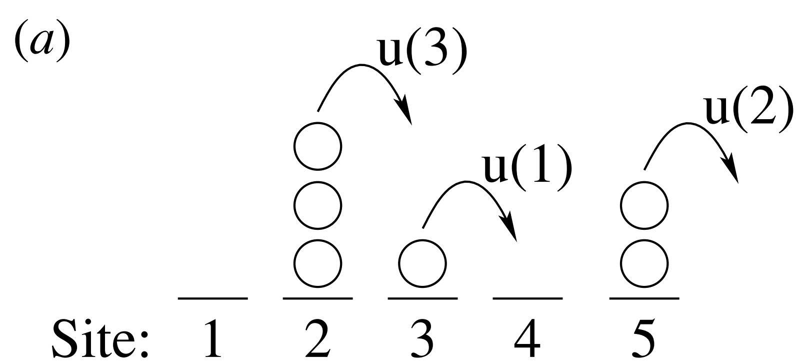
$$\tau = \sum_{i=1}^{n} l_i \quad \Rightarrow \quad \alpha' = \min\{(\alpha - 1)(\beta - 1) + 1, \alpha, \beta\}$$

$$\tau = \sum_{i=1}^{n} l_i \qquad P(\tau) = \sum_{n=1}^{\infty} P(n) F_n(\tau)$$

$$F_n(\tau) = \prod_{i=1}^{n} \int_{l_0}^{\infty} dl_i P(l_i) \delta \left( \tau - \sum_{i=1}^{n} l_i \right)$$

→ “partition function” of mass transport models

Majumdar *et al.*, PRL (2005)




$n$ = # sites (system size)
$l_i$ = # particles at site $i$
τ = total # particles

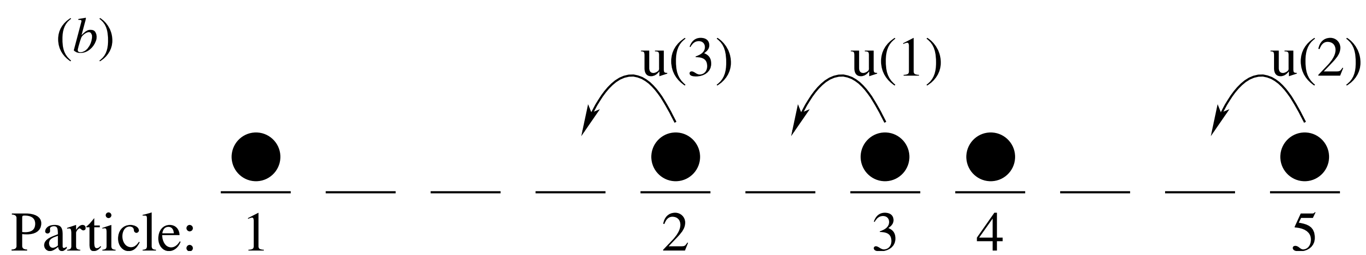
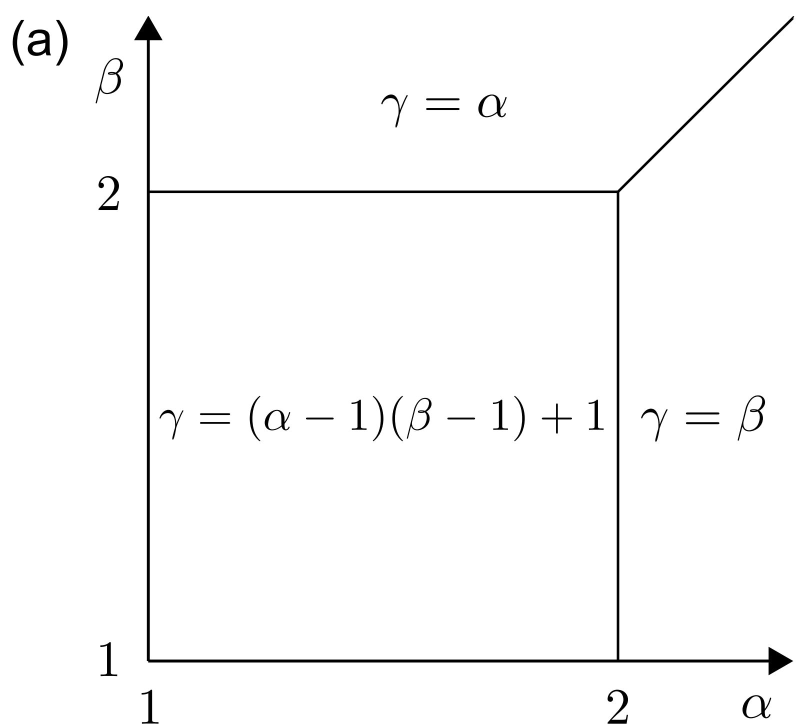


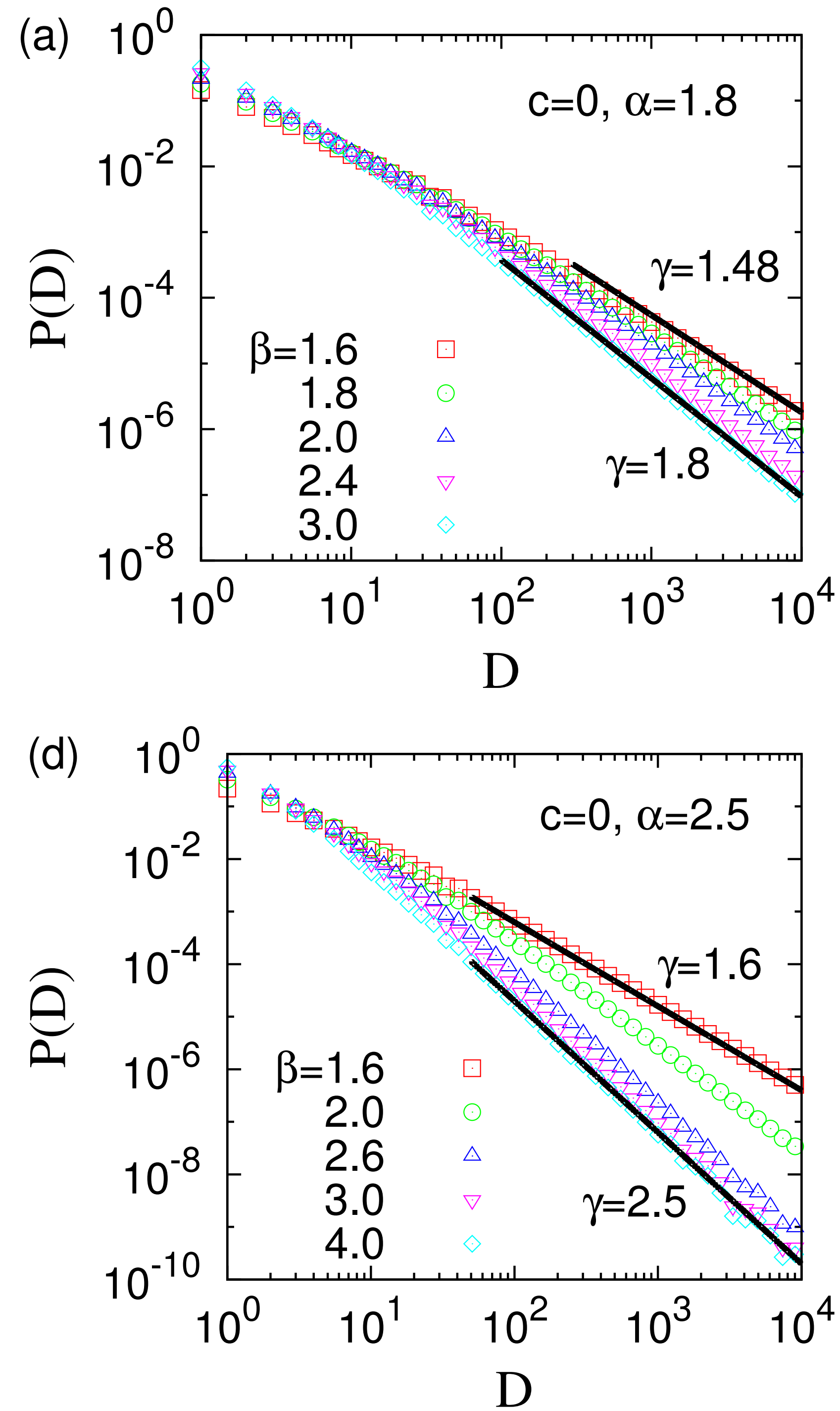

**Figure 1.** Mapping between the zero-range process and the asymmetric exclusion process.

Evans & Hanney, JPA (2005)

# Random config.

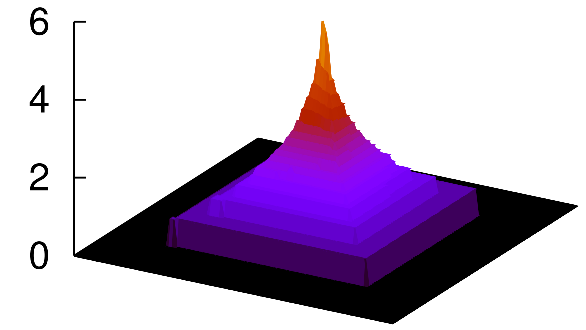
$$\gamma = \min\{(\alpha-1)(\beta-1)+1, \alpha, \beta\}$$



# Concentrated config.

- Totally correlated case (c=1):



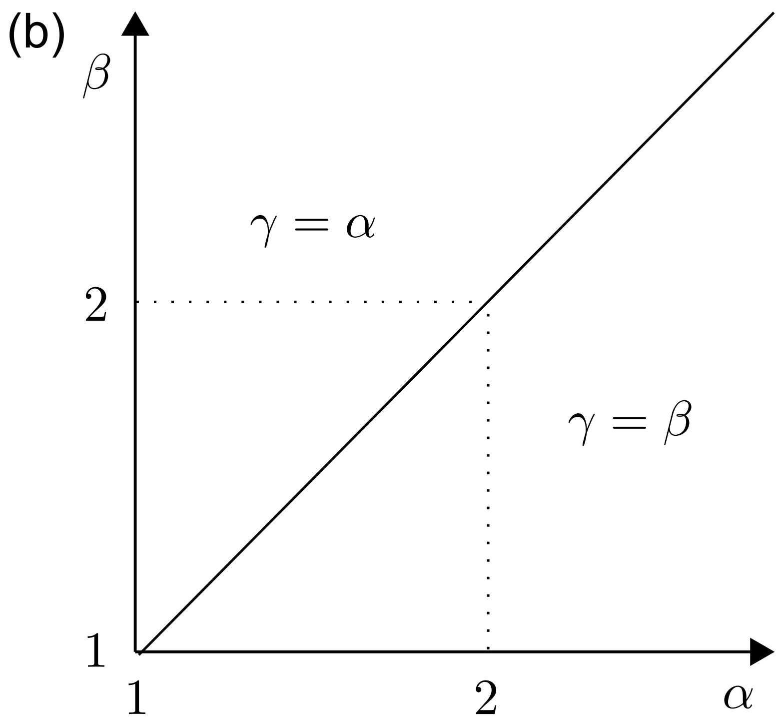

$$v(r) \simeq v_0 r^{-\mu}, \ \ \mu = \frac{2}{\alpha - 1}$$

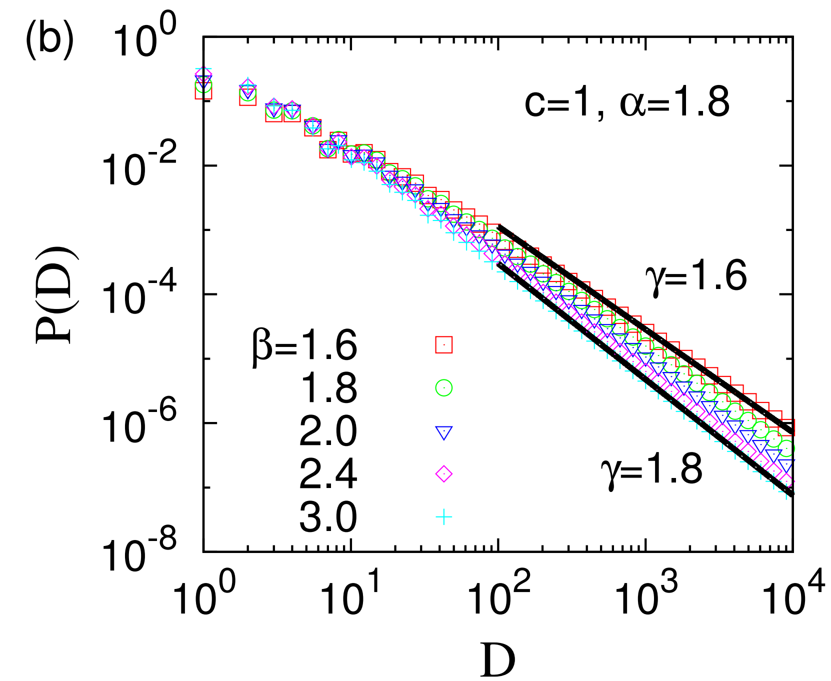
$$D(r_0, \theta_0, l, \phi) \simeq w v_0 \int_0^l r(t)^{-\mu} dt,$$

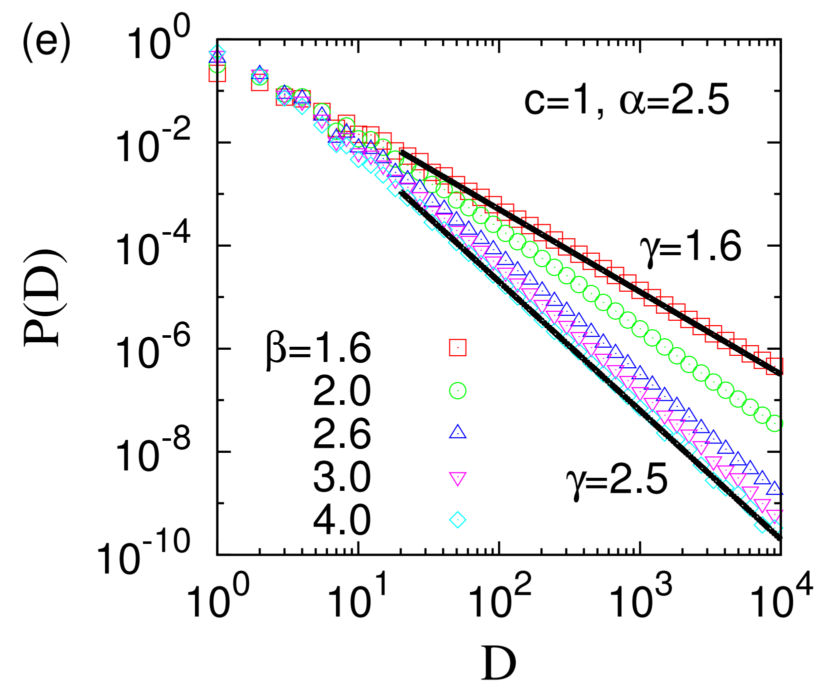
$$r(t) = \sqrt{(r_0 \cos\theta_0 + t\cos\phi)^2 + (r_0 \sin\theta_0 + t\sin\phi)^2},$$

$$\gamma = \min\{\alpha, \beta\}$$

# Concentrated config.



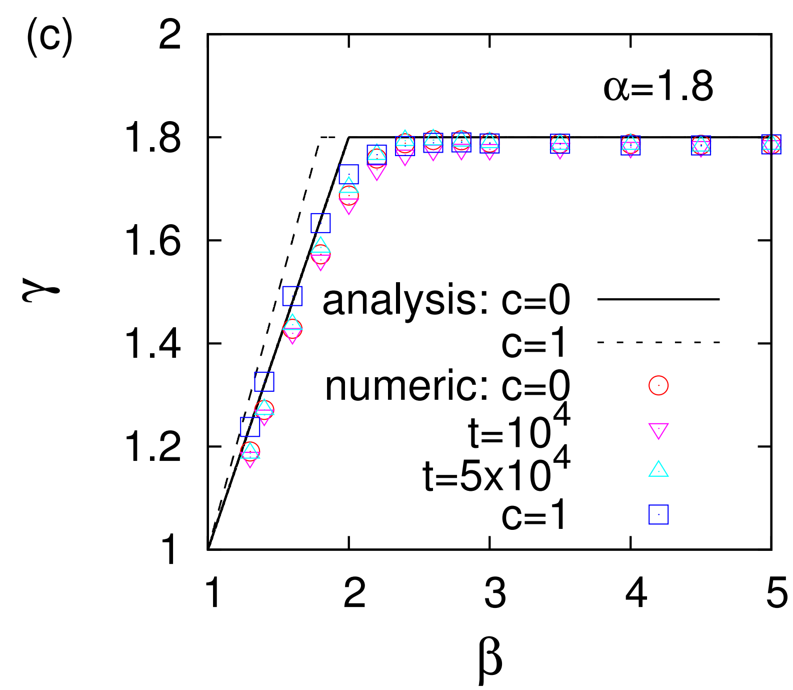



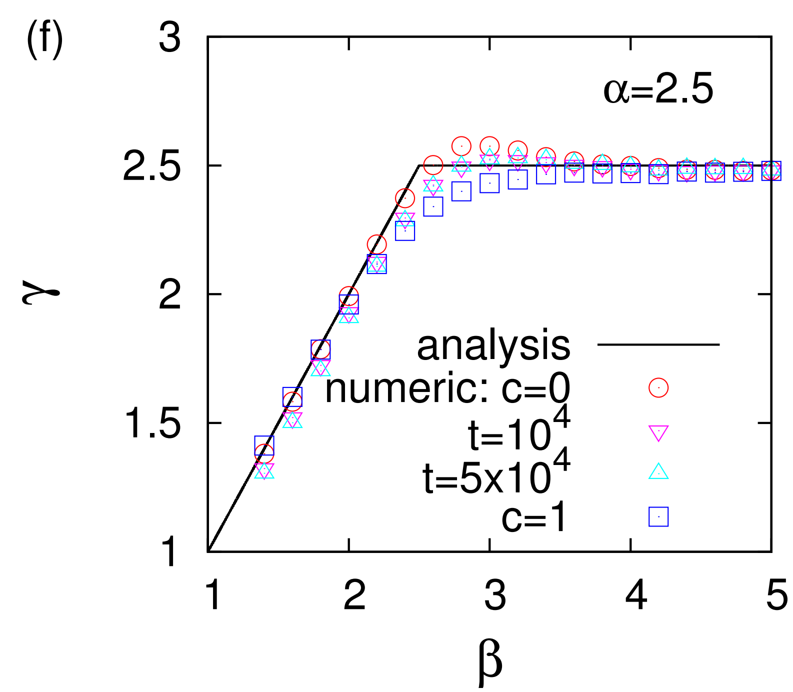
# Correlated config.

- Numerical simulations
- For $\alpha < 2$, $\gamma_{c=0} < \gamma_{c=1}$
- For $\alpha > 2$, $\gamma_{c=0} = \gamma_{c=1}$

numerical: $\gamma_{c=0} > \gamma_{c=1}$

Case-by-case~



# Vulnerability

$$D(i_0, j_0, l) = A \sum_{i=i_0}^{i_0+l-1} v_{i,j_0}$$

- If $A(v) \propto v^{\eta}$ , the effective *v* is $v' \propto v^{1+\eta}$
- The positive η: cascading due to the concentration
- The negative η: robust design of buildings etc.

# Remarks

- The risk analysis based on the thin-tailed distributions must be improved.
- More realistic simulation and theory?

https://sites.google.com/site/socialconnectome/

# Social Connectome

**This is a satellite meeting of NetSci2016.**

**Date: May 30, 2016 (Monday)**
**Venue: Dongkang D, The K-Hotel, Seoul, Korea**

## Social Connectome: The anatomy of social networks and its modeling

Understanding the structure and dynamics of social networks is crucial for investigating social
interactions between human individuals. Recently, the access to large-scale datasets on human
societal level, or Big Data, has helped to reveal a number of common features or stylized facts
social networks. However, we still do not have a complete map of social interactions due to sam
addition, many large-scale datasets are obtained from only one communication channel, while
many different channels. Moreover, the fact that social networks are continuously evolving mak
channel picture rather difficult. Hence, we propose the notion of Social Connectome that explor
social interactions at a societal level as precisely as possible, given privacy and other constraint
the Connectome in the neuroscience aiming to make a complete map of neural connections in
only for revealing and understanding various complex social phenomena, but also for possible
policy-making. For our satellite meeting, we invite the world-class researchers in the field to di
social network analysis and modeling as follows:

- social networks as a temporal network: empirical analyses and modeling
- multi-layer nature of social networks and overlapping communities
- sampling issue: how sampling only one channel may lead to a bias in network quantities
- applications to engineering and policy-making.

### Organizers

Hang-Hyun Jo (POSTECH, Chair)
Woo-Sung Jung (POSTECH)
Nobuyasu Ito (University of Tokyo & RIKEN)
Jari Saramäki (Aalto University)

### Confirmed invited speakers (alphabetical order)

Yong-Yeol Ahn (Indiana University Bloomington, USA)
Meeyoung Cha (KAIST, Korea & Facebook, USA)
Petter Holme (SKKU, Korea)
Hang-Hyun Jo (POSTECH, Korea)
Márton Karsai (ENS Lyon, France)
Kimmo Kaski (Aalto University, Finland)
János Kertész (CEU, Hungary)
Pádraig Mac Carron (University of Oxford, UK)
Yohsuke Murase (RIKEN, Japan)
Takashi Shimada (University of Tokyo, Japan)