Endogenous versus Exogenous Origins of Crises

(book sales, volatility shocks, YouTube, cyber-risks, conflicts, epilepsy, earthquakes, social crises, climate,...)

Didier Sornette
Chair of Entrepreneurial Risks
ETH Zurich
(Swiss Federal Institute of Technology, Zurich)
Department of Management, Technology and Economics
http://www.er.ethz.ch/

Collaborators:

Y. Ageon (Research scientist, Nice), J. Andersen (Research fellow, CNRS)

R. Crane and Ryan Woodard (Post-doc, ETH Zurich)

F. Deschatres (ENS student, Paris)

T. Gilbert (graduate student now at Berkeley)

A. Helmstetter (post-doc, now at CNRS Grenoble)

Y. Malevergne (Professor Univ, of Lyon, France)

T. Maillart (PhD, ETH Zurich), Jonathan Gysel, Stefan Frei

J.F. Muzy (Research Fellow CNRS)

B. Roehner (Professor, Univ. Paris)

CRISES and EXTREME EVENTS

- dramatic and rapid change of a system which is the culmination of a complex preparatory stage.

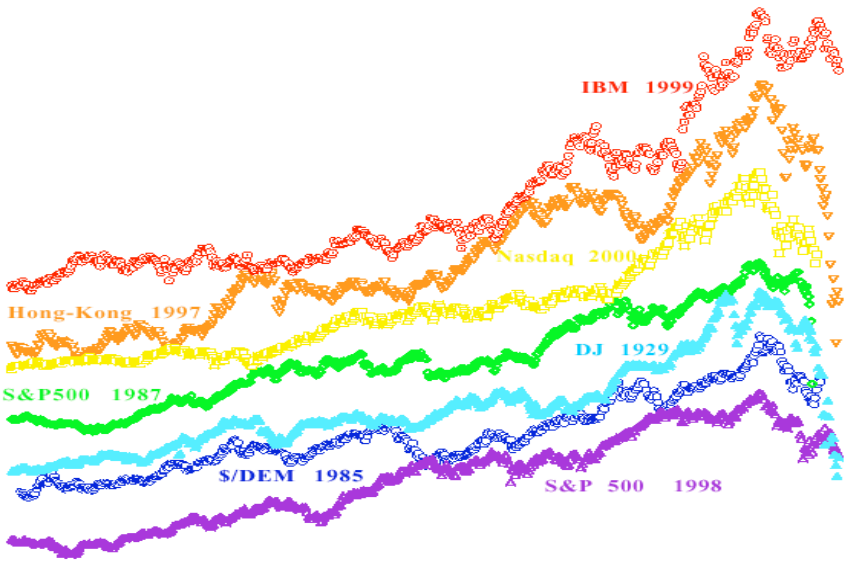
- fundamental societal impacts

- large natural catastrophes

1. earthquakes,
2. volcanic eruptions,
3. hurricanes and tornadoes,
4. landslides, avalanches,
5. lightning strikes,
6. meteorite/asteroid impacts,
7. catastrophic events of environmental degradation,

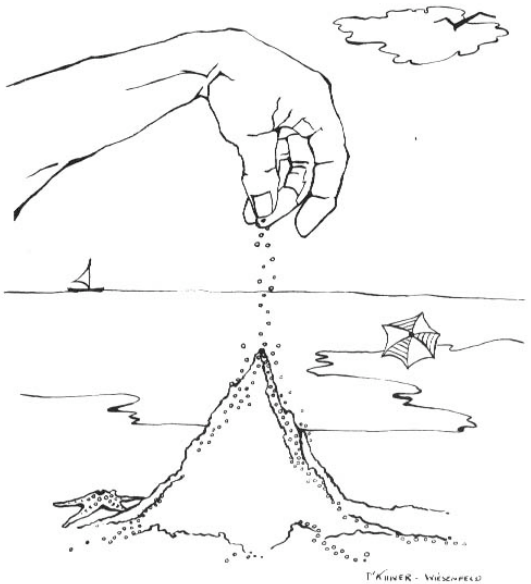
EXTREME EVENTS in SOCIO-ECONOMIC SYSTEMS

- failure of engineering structures,
- crashes in the stock market,
- social unrest leading to large-scale strikes and upheaval,
- economic drawdowns on national and global scales,
- regional power blackouts,
- traffic gridlock,
- diseases and epidemics, etc.



- **Self-organization?**

Extreme events are just part of the tail of power law distribution due to "self-organized criticality"? (endogenous)



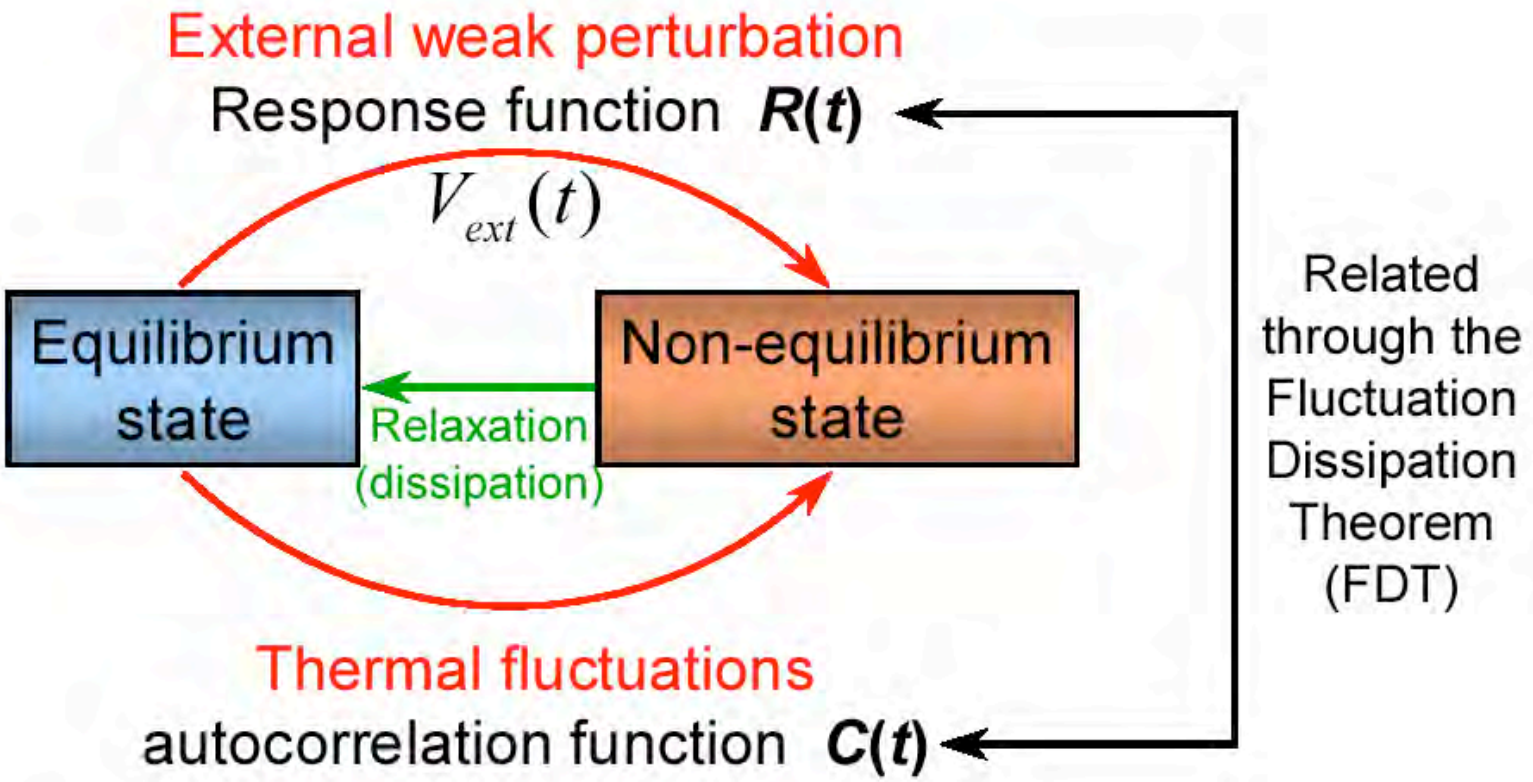
Artwork by Elaine Wiesenfeld
(from Bak, How Nature Works)

- **"Catastrophism": extreme events require extreme causes that lie outside the system (exogenous)**

- **A mixture? How would it work?**

Guidelines from Physics: perturb and study the response

Linear Response Theory



Endogenous versus Exogenous

Extinctions
- -meteorite at the Cretaceous/Tertiary KT boundary
- -volcanic eruptions (Deccan traps)
- -self-organized critical events

Discoveries
- -serendipity
- -maturation

Financial crashes
- -external shock
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Volatility bursts in financial time series
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- -cumulative effect of "small" news

Earthquakes
- -tectonic driving
- -triggering

Immune system
- -external viral or bacterial attack
- - " internal" (dis-)organization

Parturition
- -mother/foetus triggered?
- -mother-foetus complex?

Brain (learning)
- -external inputs
- -internal self-organization and reinforcements (role of sleep)

Aviation industry recession
- -September 11, 2001
- -structural endogenous problems

Commercial success and sales
- -Ads
- -epidemic network

Recovery after wars?
- -internally generated (civil wars)
- -externally generated

Social unrests
- -triggering factors
- -rotting of social tissue

The method of critical events in economics and social sciences

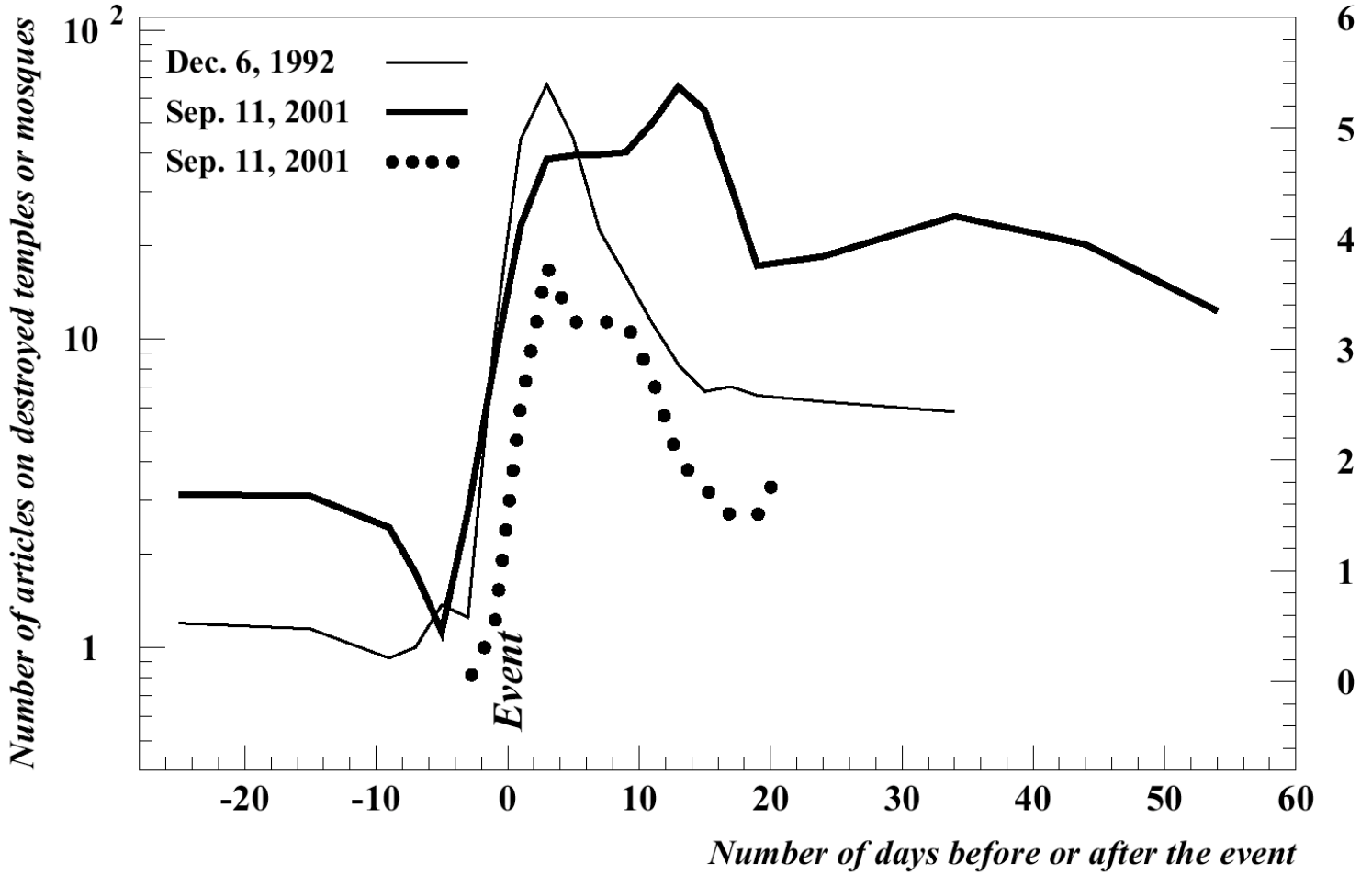


Fig.1: Aftershocks of two critical events. December 6, 1992 was marked by the destruction of the Ayodhya mosque in India which sparked a wave of anti-Hindu reactions; September 11, 2001 was marked by the destruction of the Word Trade Center in New York which sparked a wave of anti-Islamic reactions. The origin of the horizontal scale corresponds to the day when the critical event occurred. The two solid lines show the number of articles writing on the destruction of Hindu temples or mosques respectively (scale on the left-hand side); the dotted line shows the number of mosques actually destroyed or damaged (scale on the right-hand side). **(Roehner and Sornette, 2004)**

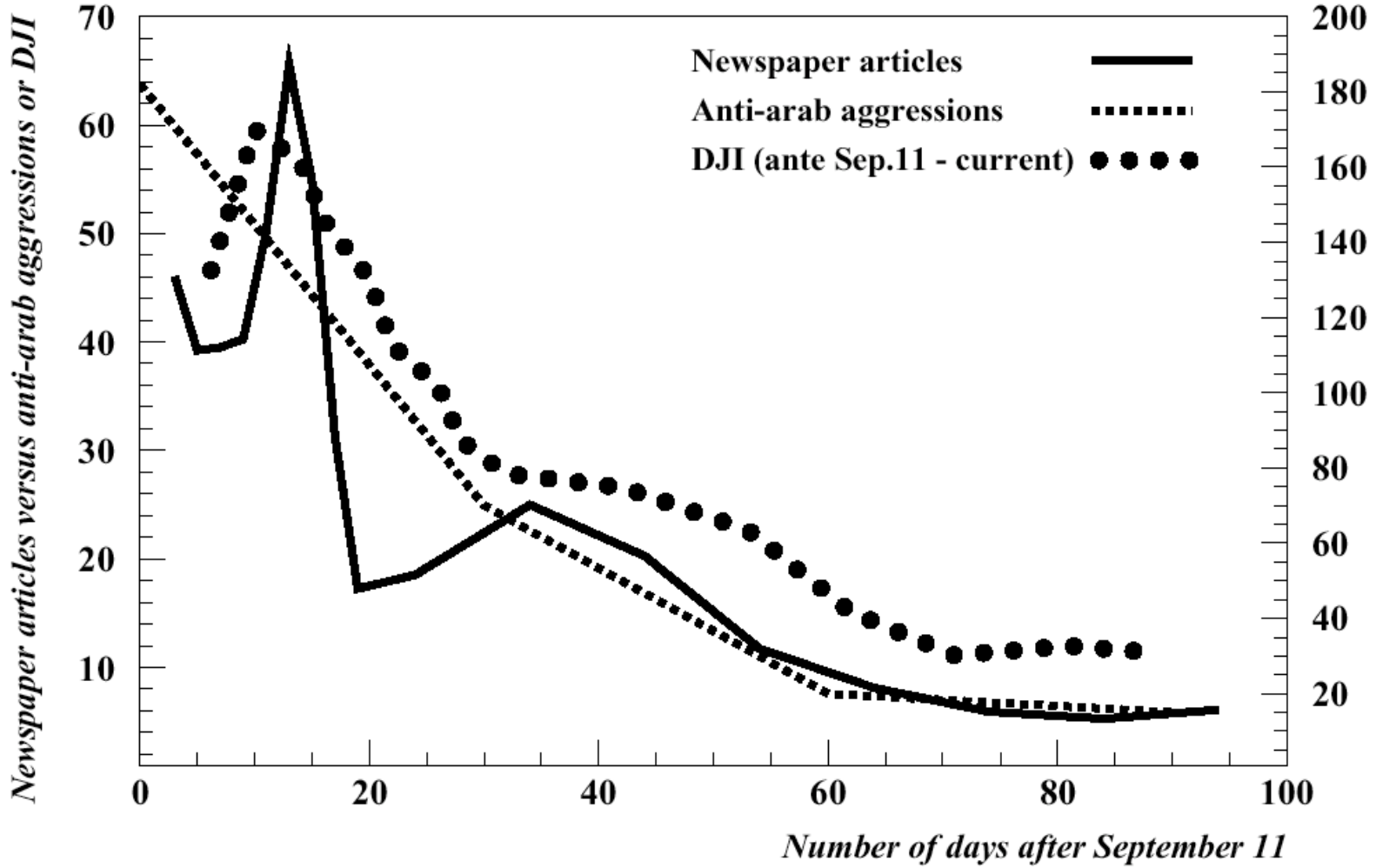


Fig.2: Relaxation curves after the shock of September 11. The solid line curve is the same as in Fig.1 but over a larger time interval; the broken line (scale on the right-hand side) shows the number of anti-arab aggressions in California in the three months after September 11; the dotted line shows the changes in the level of the Dow Jones Index with respect to its pre-Sep.11 level as given by the difference DJI(pre-9/11)-DJI(current). The tails of all three curves are well-approximated by power laws $\sim 1/t^{\alpha}$, with exponents α comprised between -1.4 and -2.2: $\alpha_1 = -1.8 \pm 0.7$ (newspaper articles), $\alpha_2 = -1.4 \pm 0.5$ (anti-arab agressions) and $\alpha_3 = -2.2 \pm 1.6$ (DJI). **(Roehner and Sornette, 2004)**

The model

Timing of human activity

$$\phi(t) \sim 1/t^{1+\theta}$$

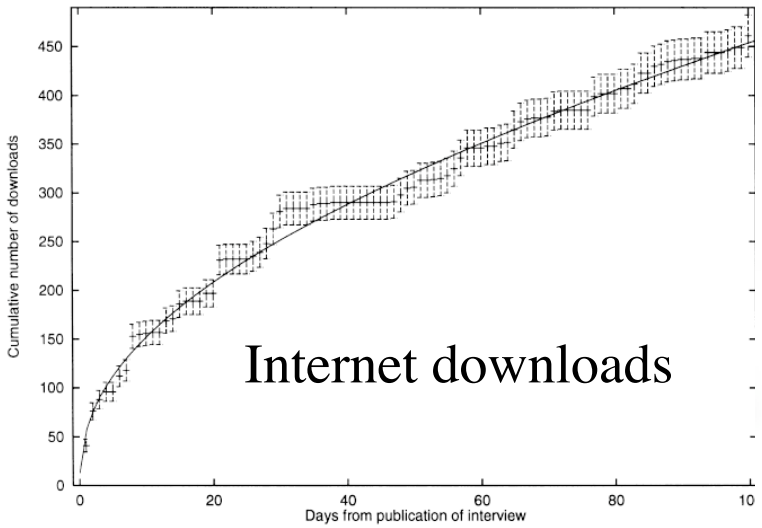
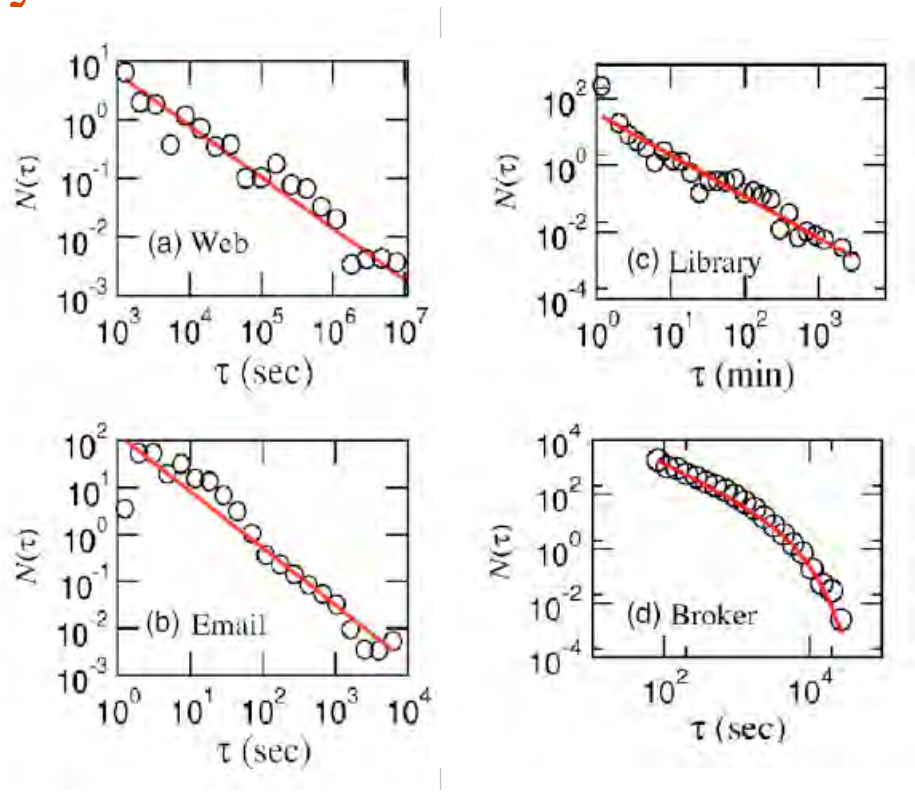


Fig. 1. Cumulative number of downloads N as a function of time t from the appearance of the intervie on Wednesday the 14 April 1999. The fit is $N(t) = [a/(1-b)]t^{1-b} + ct$ with $b \approx 0.58$.

Sornette & Johansen, Physica A 276, 338

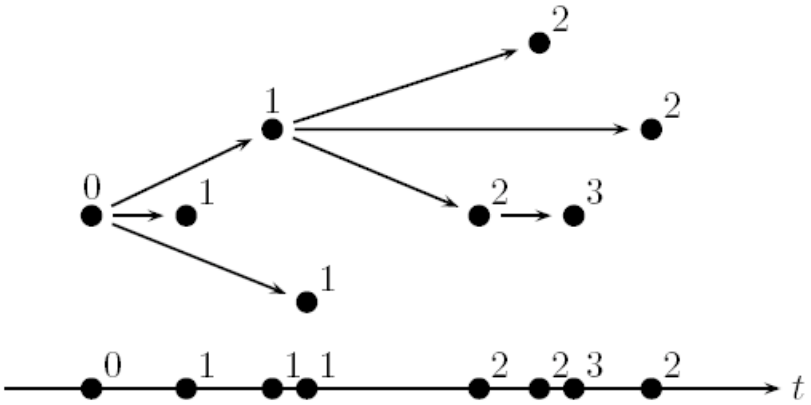


Vazquez, Oliveira, Dezo, Goh, Kondor, Barabasi, PRE 73, 036127

The model

Epidemic branching process

The sum of all activity modeled as a “self-excited” Hawkes conditional Poisson branching process

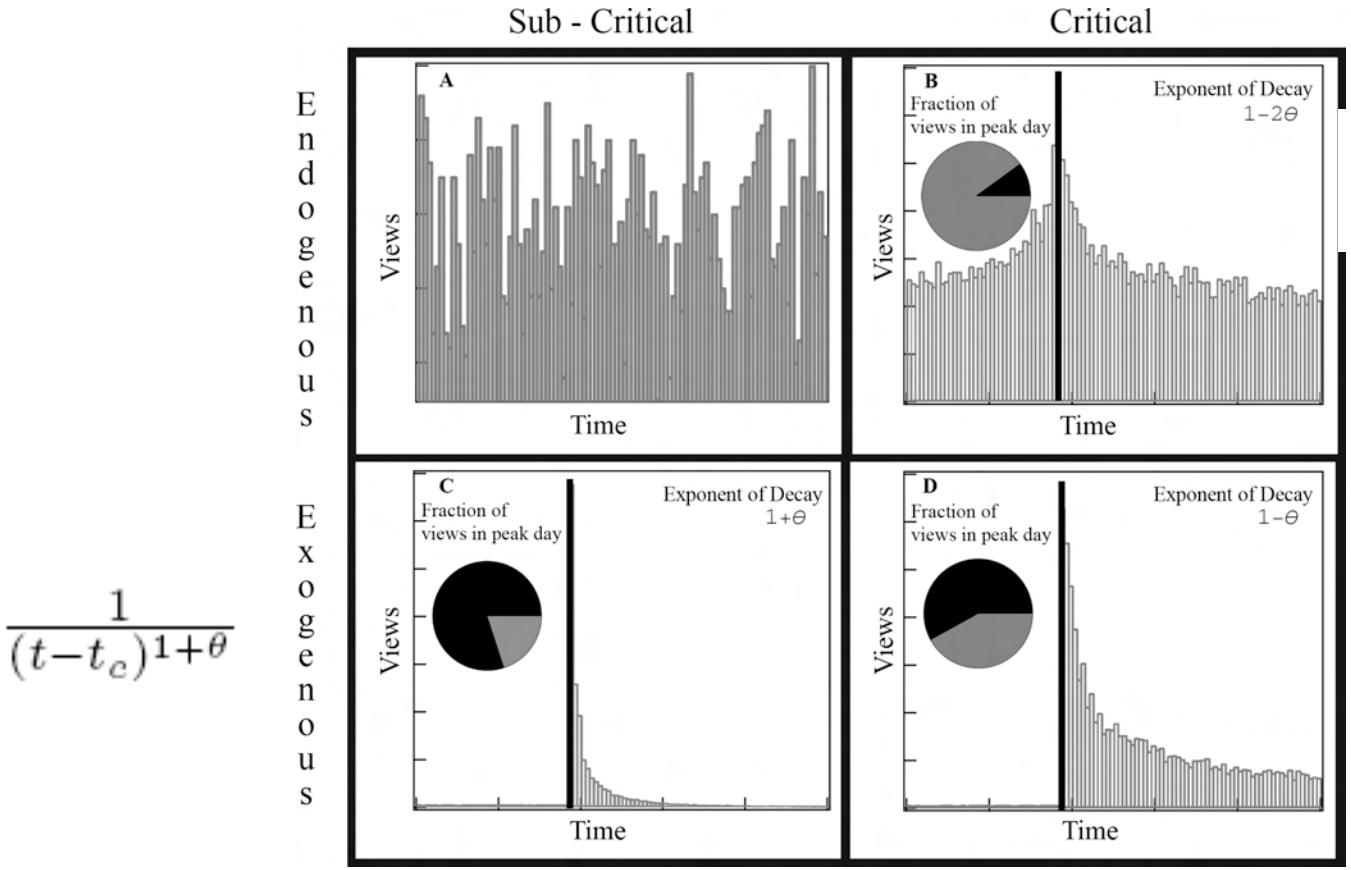


$$\lambda(t) = \eta(t) + \sum_{i|t_i \le t} \mu_i \phi(t - t_i)$$

$$\phi(t) \sim 1/t^{1+\theta}$$

$$A(t) \equiv \langle \lambda(t) \rangle = \eta(t) + n \int_{-\infty}^{t} \phi(t - \tau) A(\tau) d\tau$$

Predictions of the model



$$\frac{1}{|t-t_c|^{1-2\theta}}$$

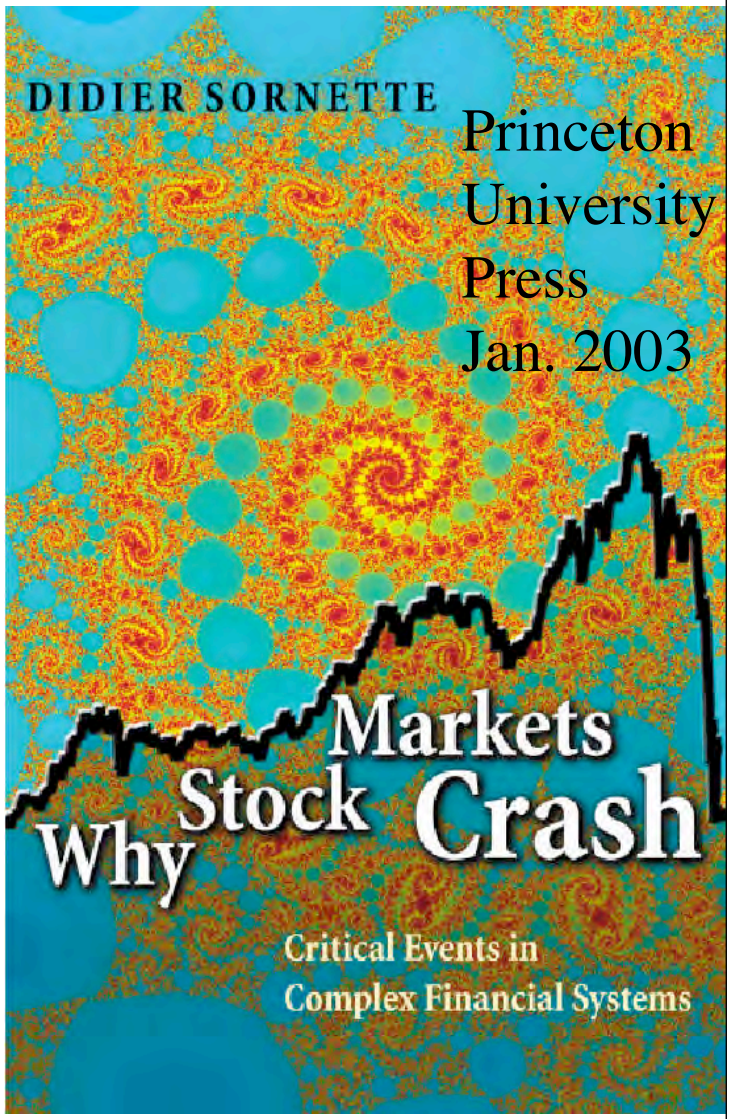
$$\frac{1}{(t-t_c)^{1+\theta}}$$

$$\frac{1}{(t-t_c)^{1-\theta}}$$

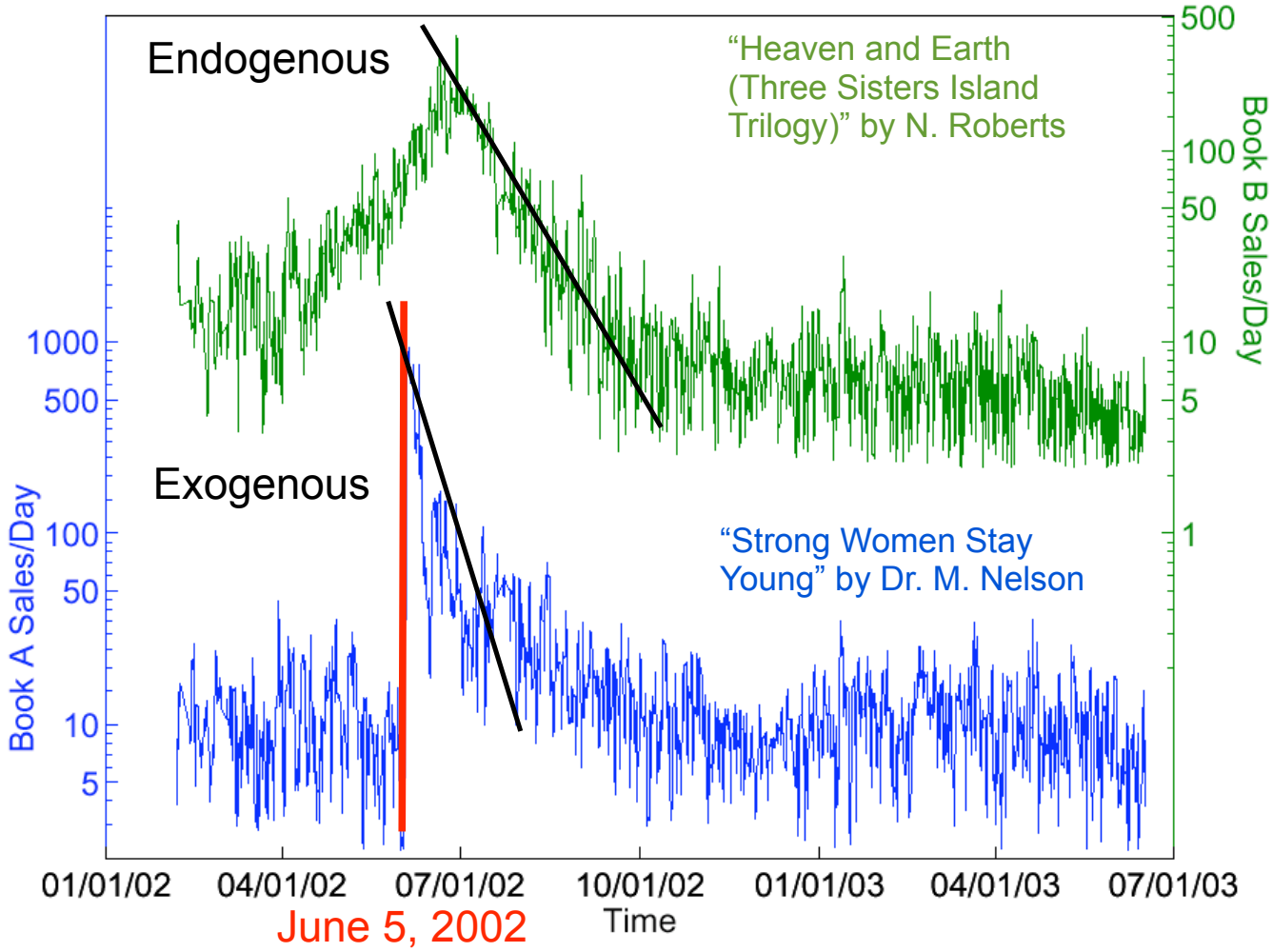
Dynamics classified by type of disturbance (endo/exo)
&
criticality of the network (sub-critical/critical)

The Original "Crisis"

- On Friday January 17, 2003, Sornette's recent book jumped to rank # 5 on Amazon.com's sales ranking (with Harry Potter as #1!!!)
- Two days before: release of an interview on MSNBC's MoneyCentral website

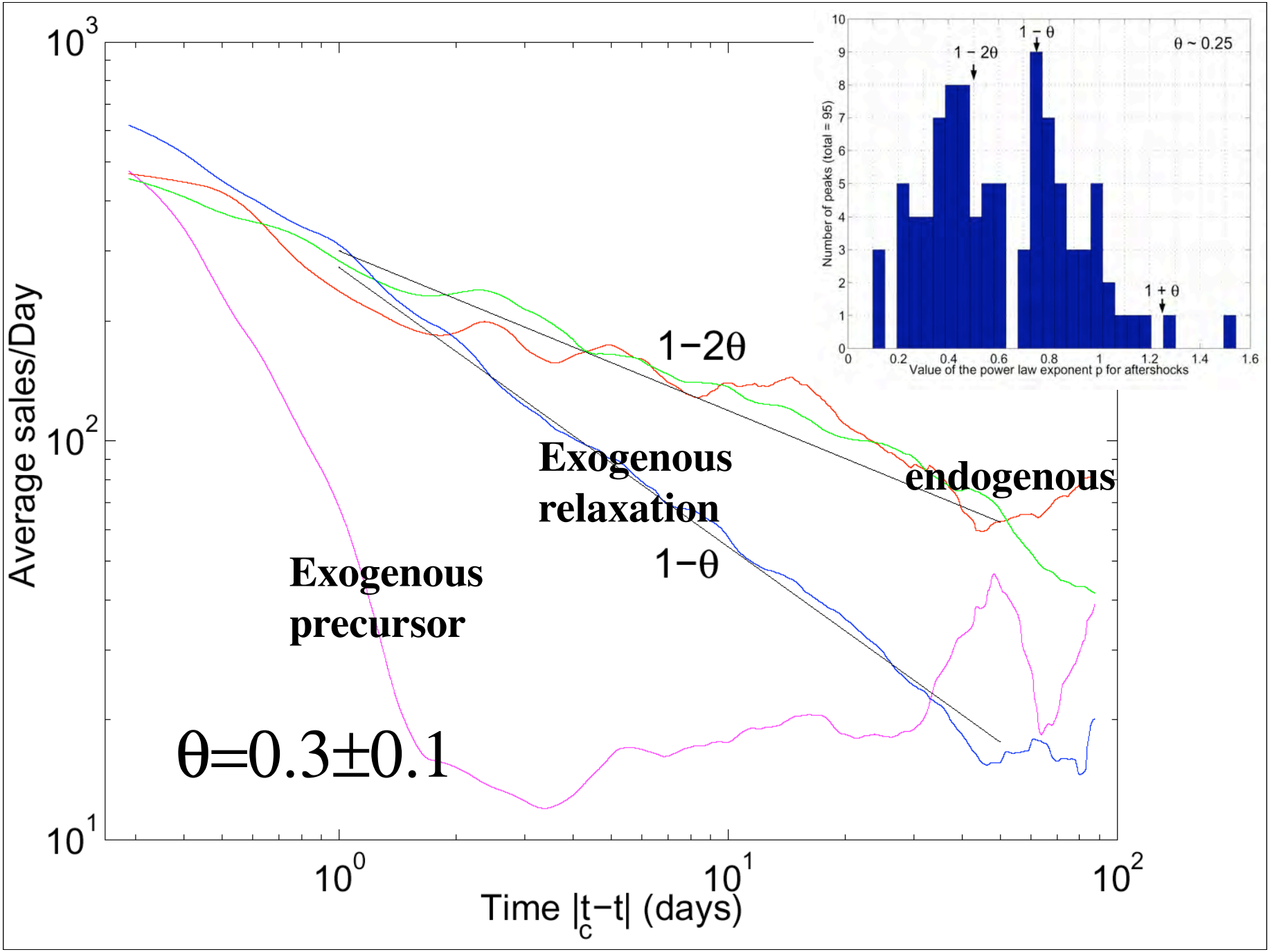


Book sales dynamics



June 4, 2002: New York Times article crediting the "groundbreaking research" of Dr. Nelson

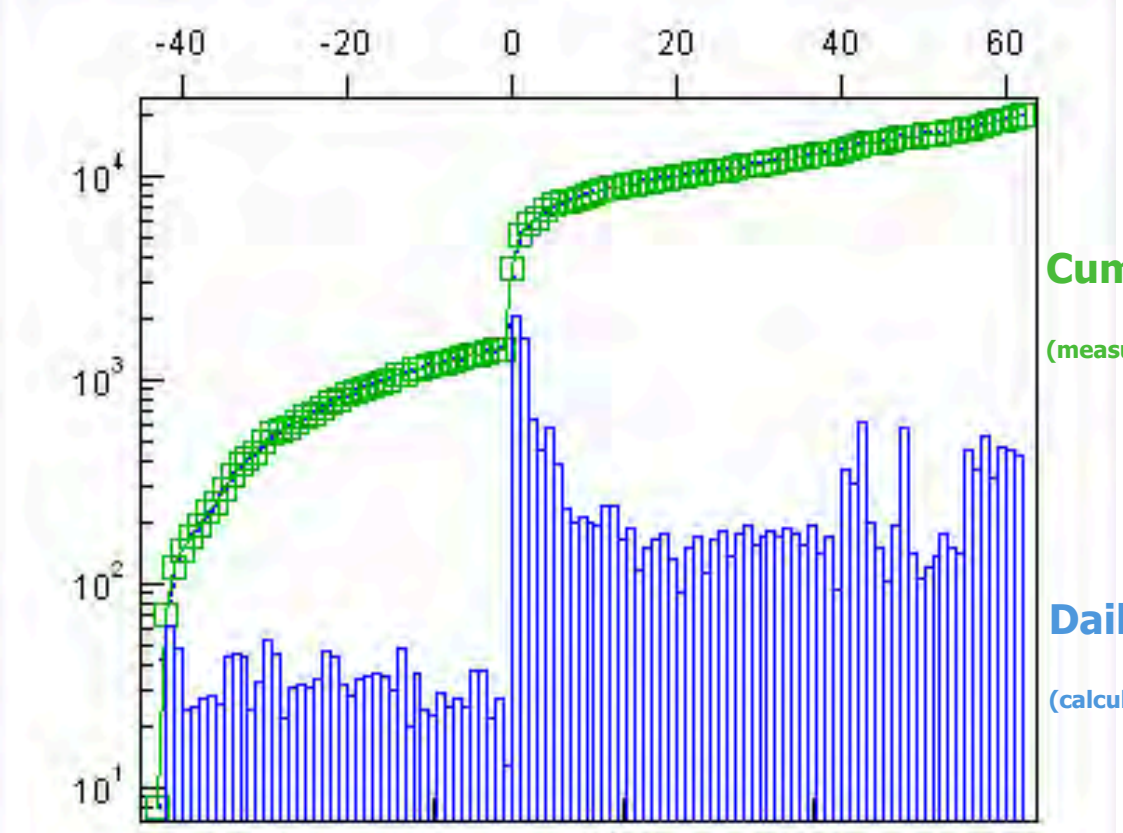
D. Sornette et al., Phys. Rev. Letts. 93 (22), 228701 (2004)


Average sales/Day
Time |t_c−t| (days)
10^3
10^2
10^1
10^0
10^1
10^2
1−2θ
1−θ
Exogenous relaxation
endogenous
Exogenous precursor
θ=0.3±0.1
Number of peaks (total = 95)
Value of the power law exponent p for aftershocks
1 − 2θ
1 − θ
1 + θ
θ ~ 0.25

A Shocking Look At...

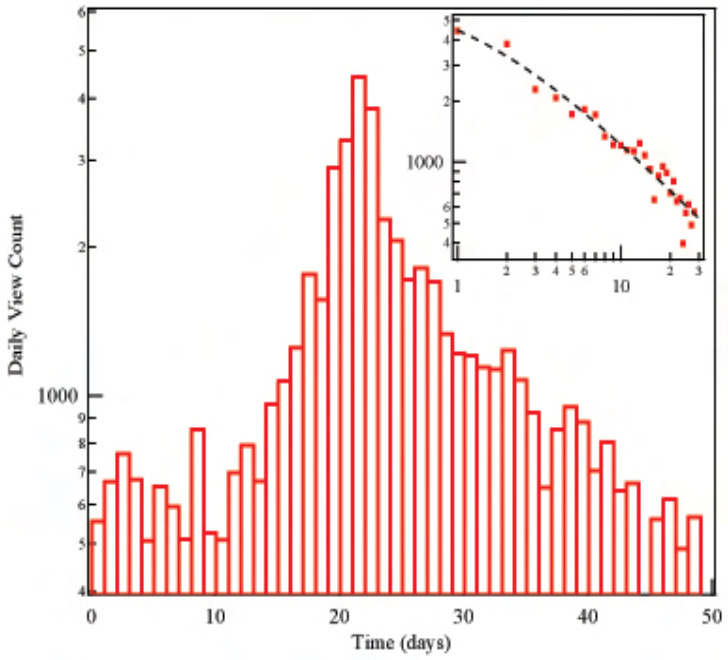
Riley Crane, Didier Sornette
ETH Zurich, D-MTEC
Chair of Entrepreneurial Risks

What is being measured?

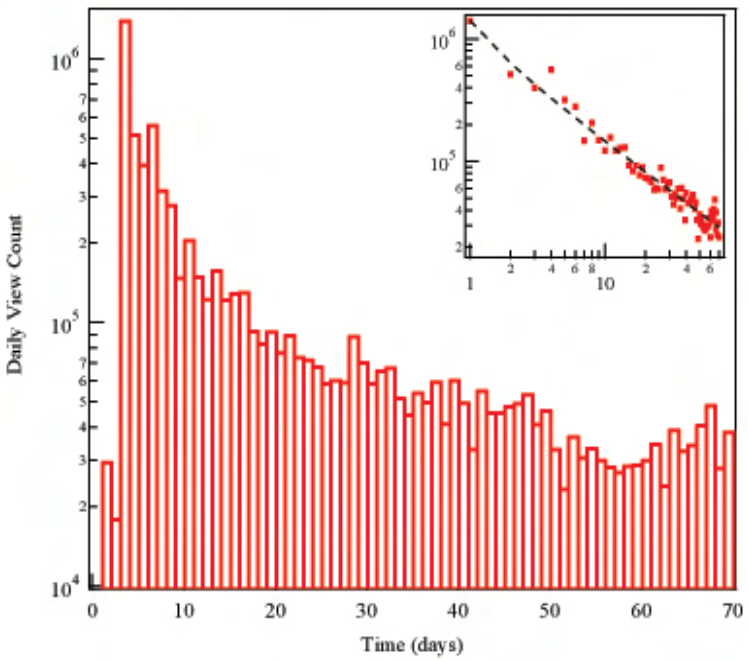


Endogenous and Exogenous Activity

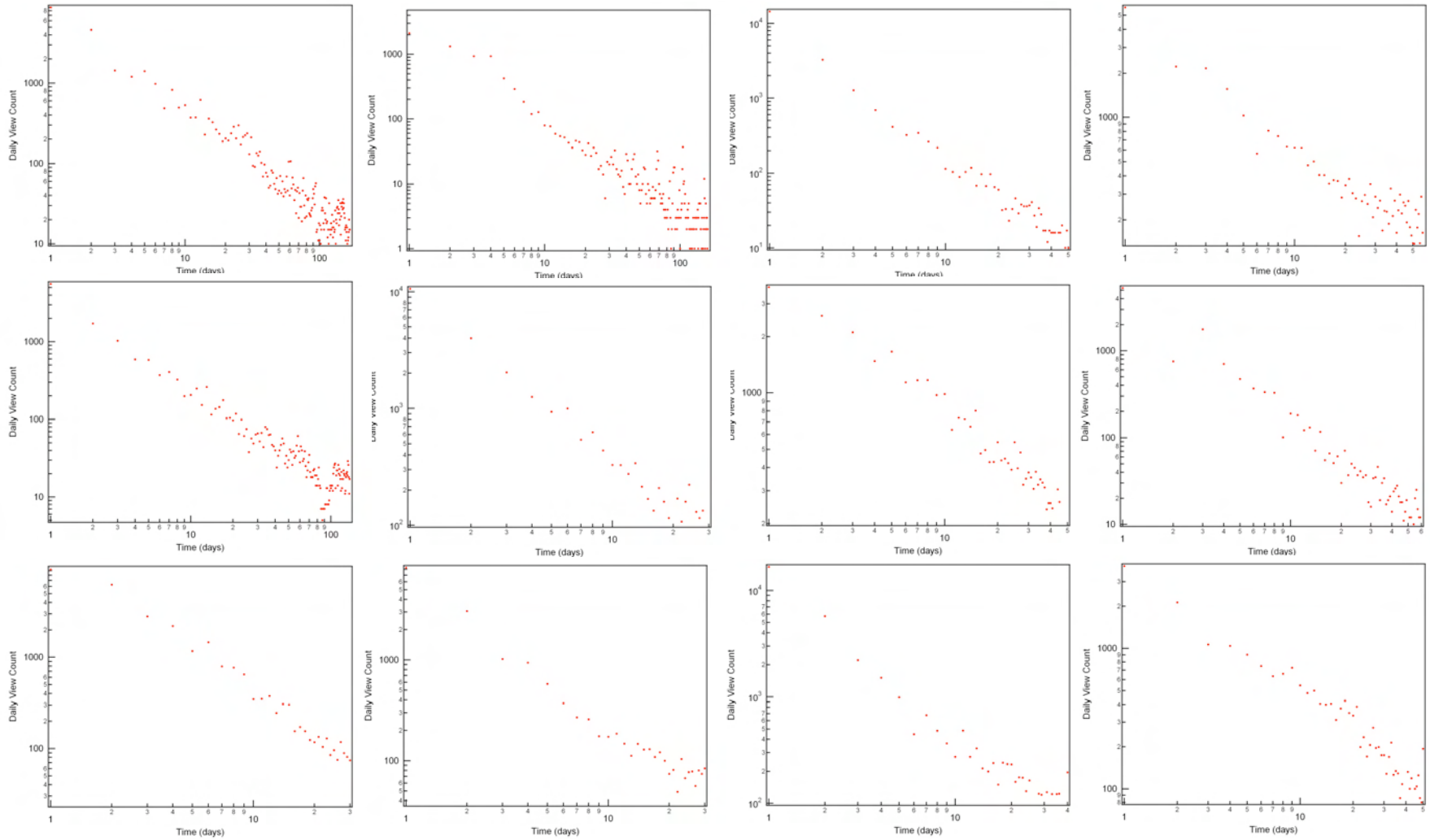
Endogenous



Exogenous

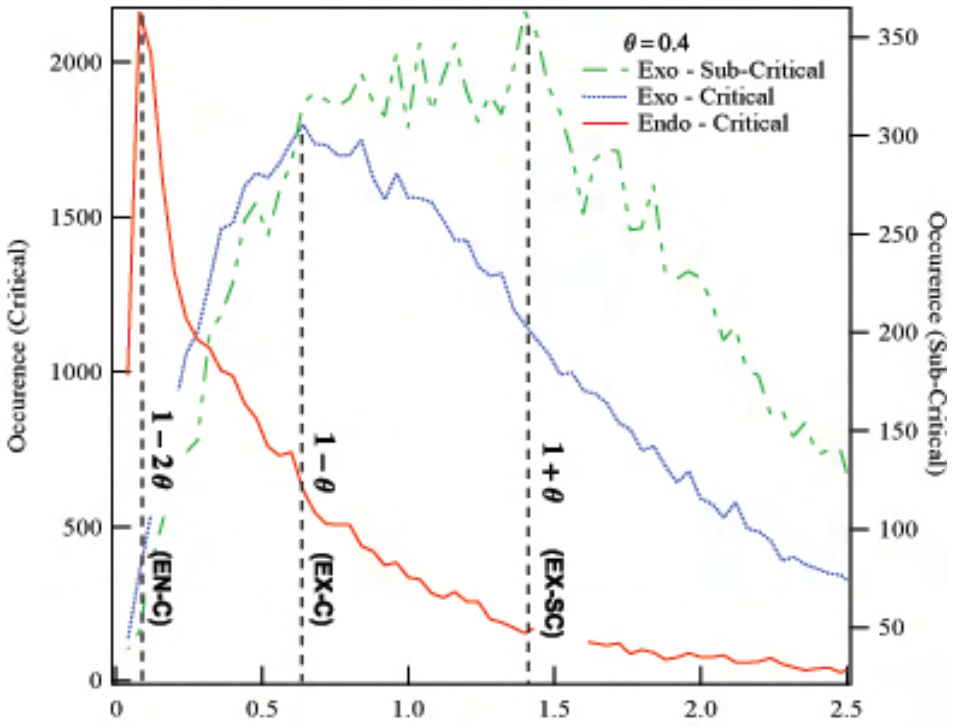


Typical Relaxation after a burst of activity



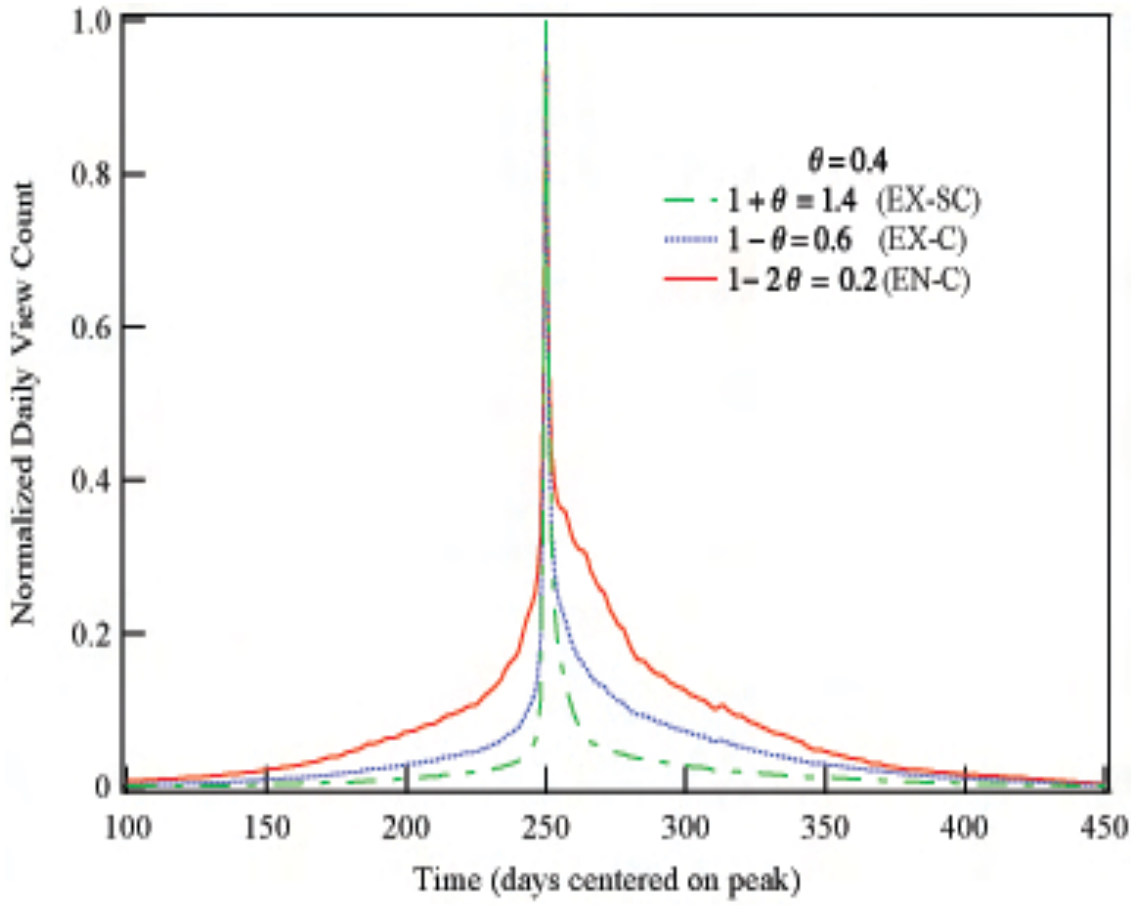
Relaxation Exponents

Distribution of Exponents

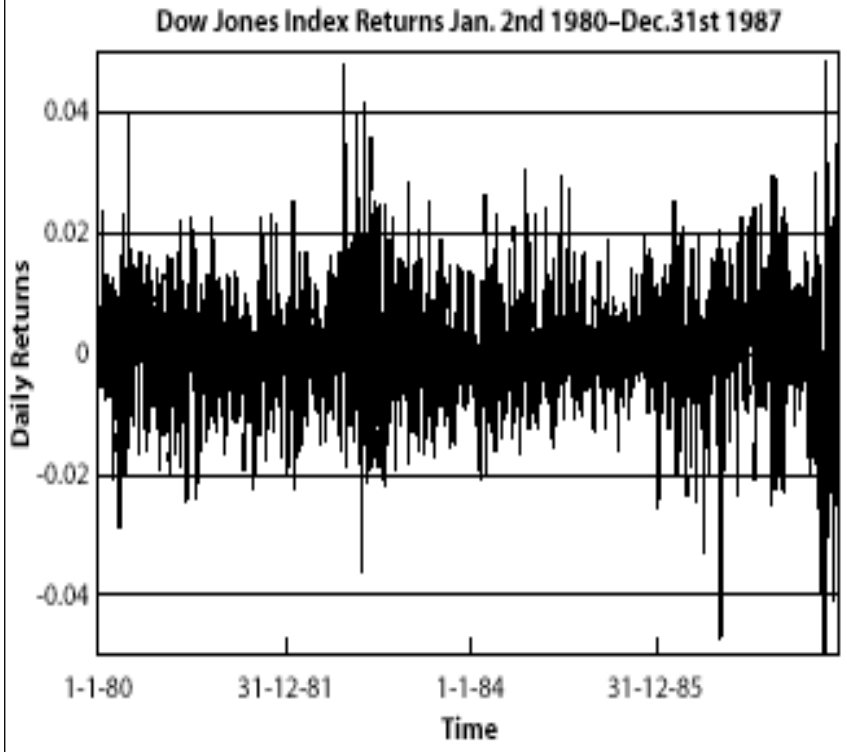


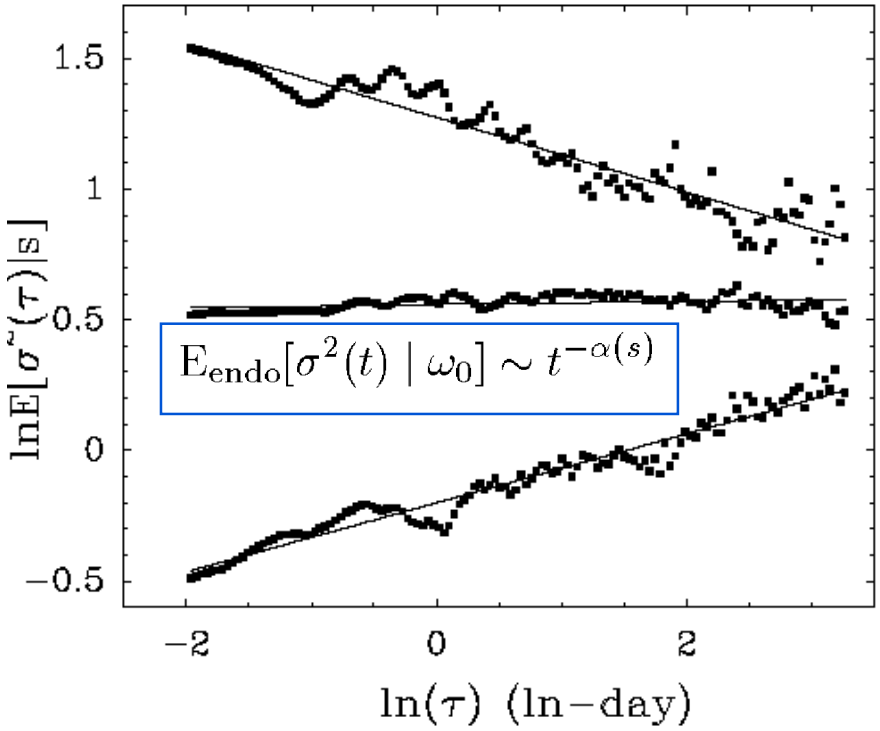
q = 0.4

Non-parametric superposition

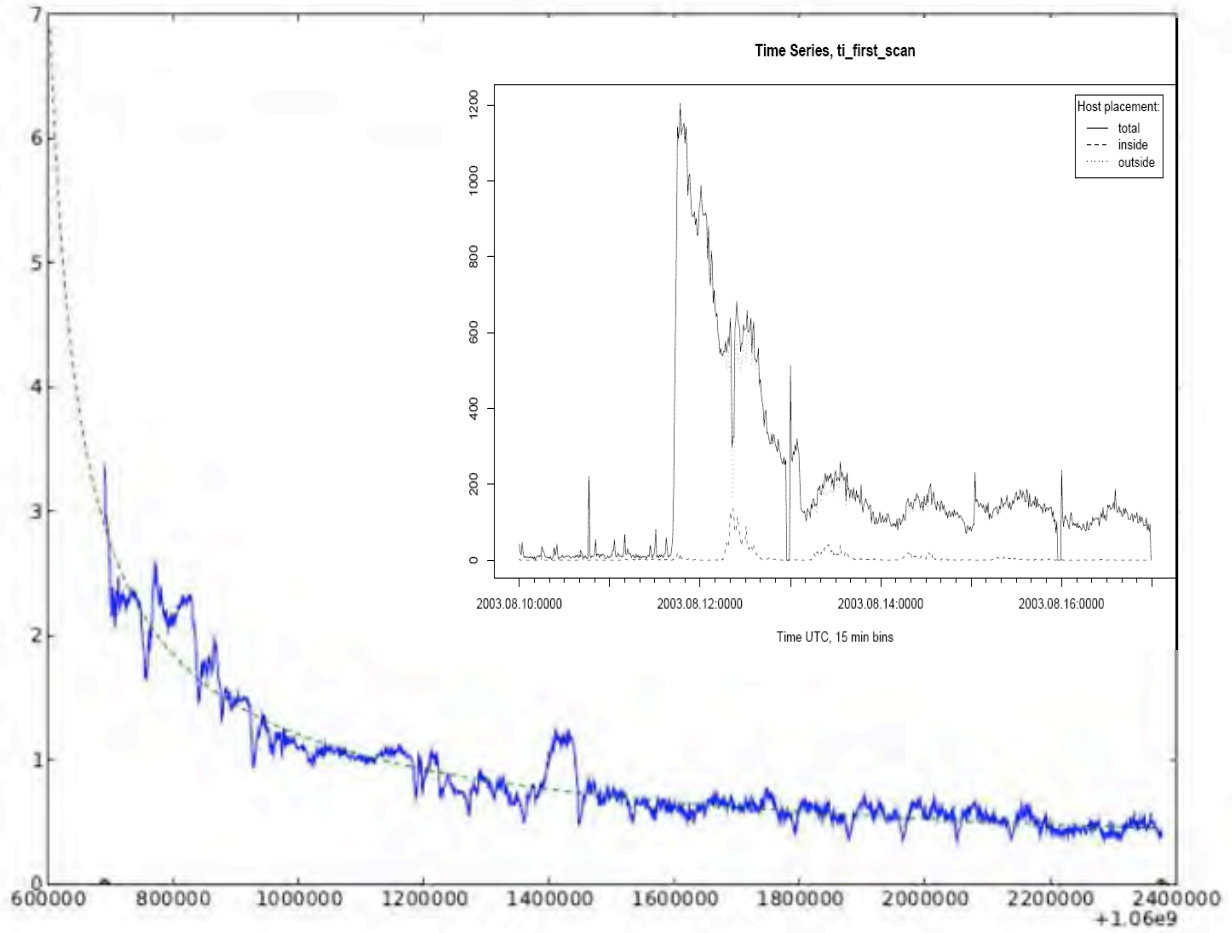


Financial volatility foreshocks and aftershocks





Cyber-risks



Power-law fit to the decay of the rate of active infections after removing seasonality, following the outbreak of the blaster virus on the Swiss SWITCH network, as a function of time from 2003 to 2008.

Application to conflict early warning

with P. Meier (Tufts Univ., Boston) and R. Woodard (ETH Zurich)

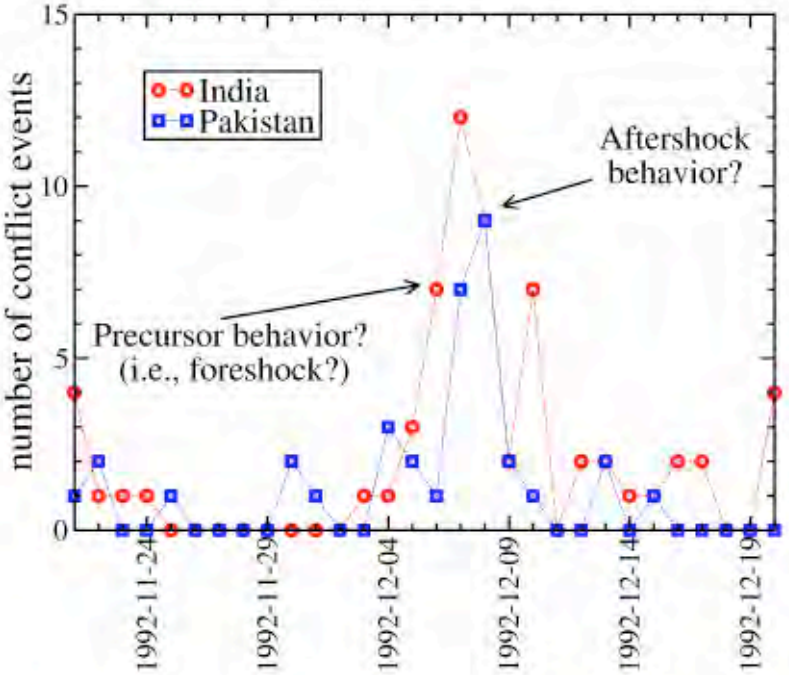
- Data extracted using Virtual Research Associates, Inc. (VRA) Reader `http://www.vranet.com`
- Software parses Reuters Business Briefing newswire
- Database of *source* and *target* actors, *type of event*
- 157 event types, 'all' countries, aggregated into *conflict* and *cooperation* time series, 1990-2005

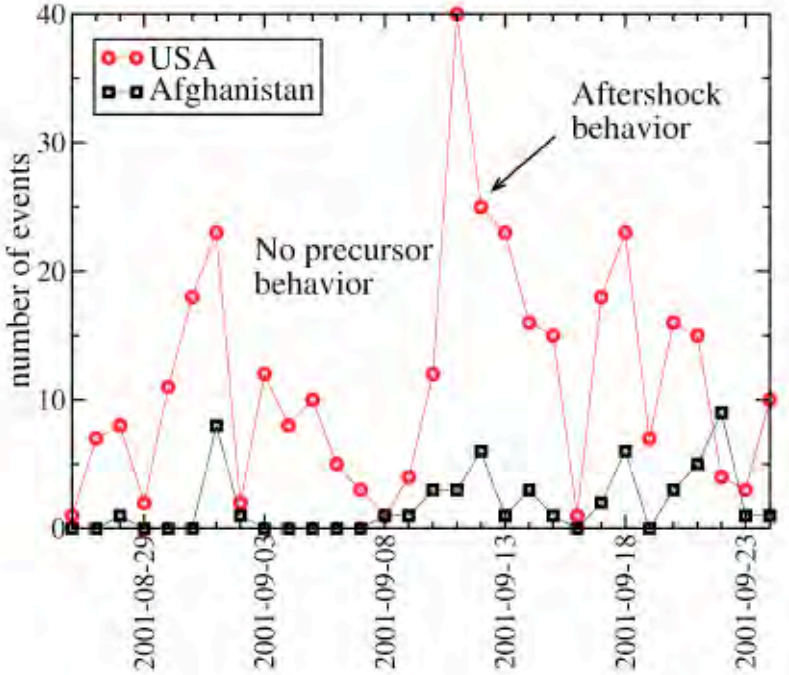
24 conflict event types

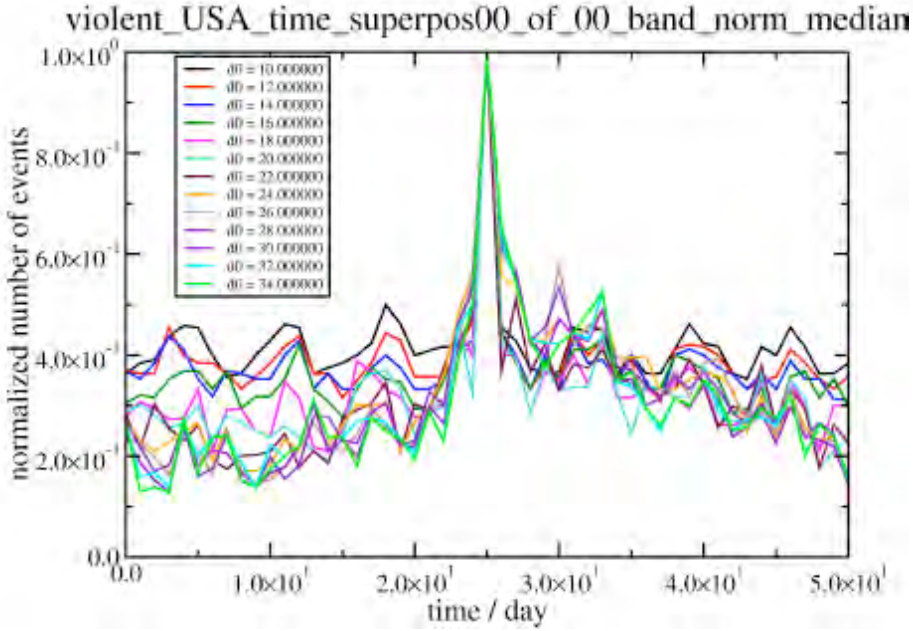
Abduction	Armed actions
Armed battle	Arrest and detention
Artillery attack	Assassination
Beatings	Bodily punishment
Coups and mutinies	Criminal arrests
Crowd control	Force use
Hijacking	Hostage and kidnapping
Mine explosion	Missile attack
Physical assault	Political arrests
Riot	Sexual assault
Small arms attack	Suicide bombing
Torture	Vehicle bombing

27 cooperation event types.

Acknow. respons.	Agree to mediation
Agree to negotiate	Agree to peacekeeping
Agree to settlement	Apologize
Collaborate	Demobilize armed forces
Ease sanctions	Empathize
Engage in negotiation	Evacuate victims
Forgive	Grant asylum
Host a meeting	Improve relations
Mediate talks	Observe truce
Offer peace proposal	Offer to Negotiate
Offer to mediate	Promise to mediate
Provide shelter	Relax curfew
Request mediation	Request withdrawal or ceasefire
Travel to meet	


number of conflict events
India
Pakistan
Aftershock behavior?
Precursor behavior? (i.e., foreshock?)
1992-11-24
1992-11-29
1992-12-04
1992-12-09
1992-12-14
1992-12-19

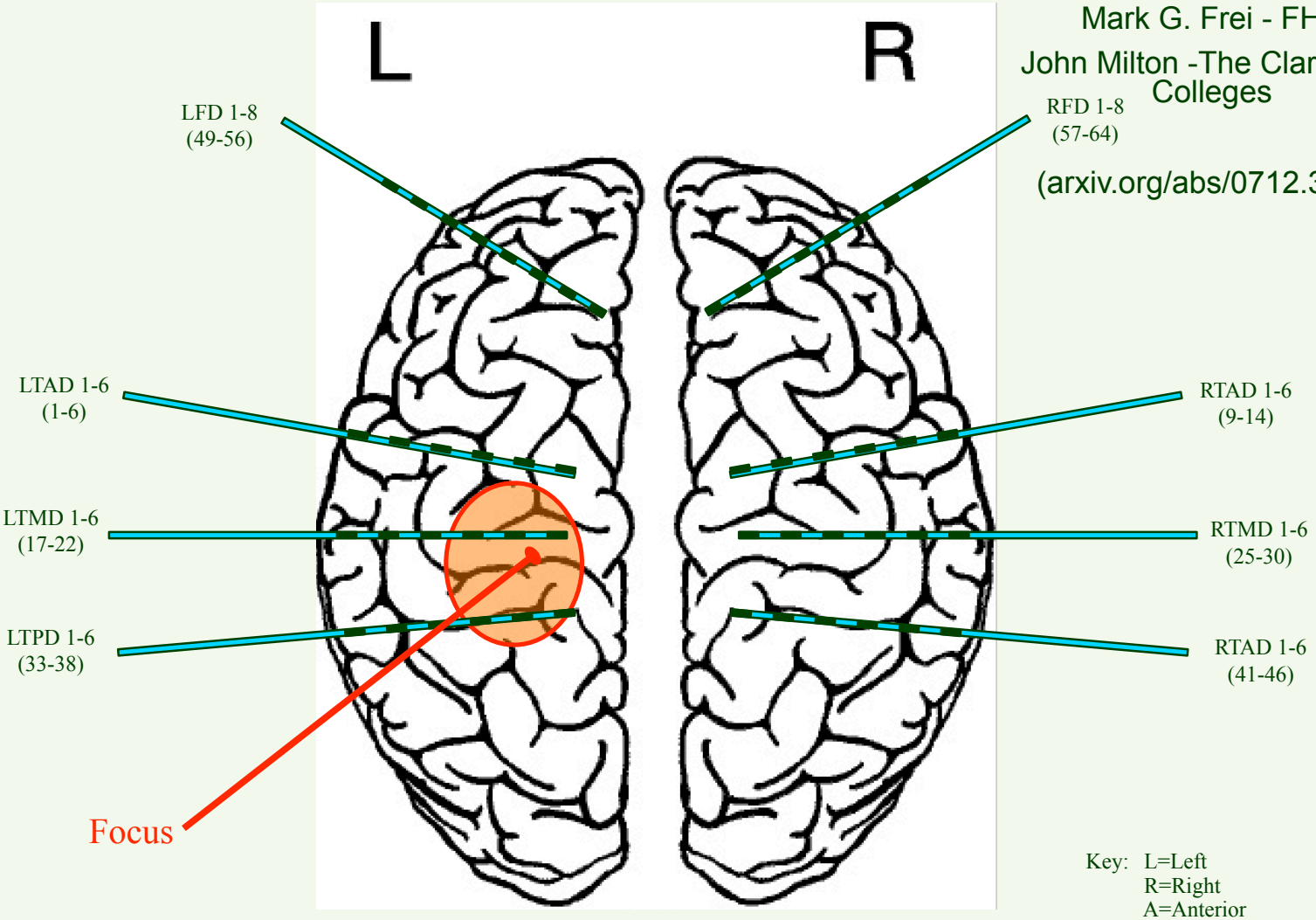

number of events
USA
Afghanistan
Aftershock behavior
No precursor behavior
2001-08-29
2001-09-03
2001-09-08
2001-09-13
2001-09-18
2001-09-23


violent_USA_time_superpos00_of_00_band_norm_median
normalized number of events
time / day

Epileptic Seizures – Quakes of the Brain?

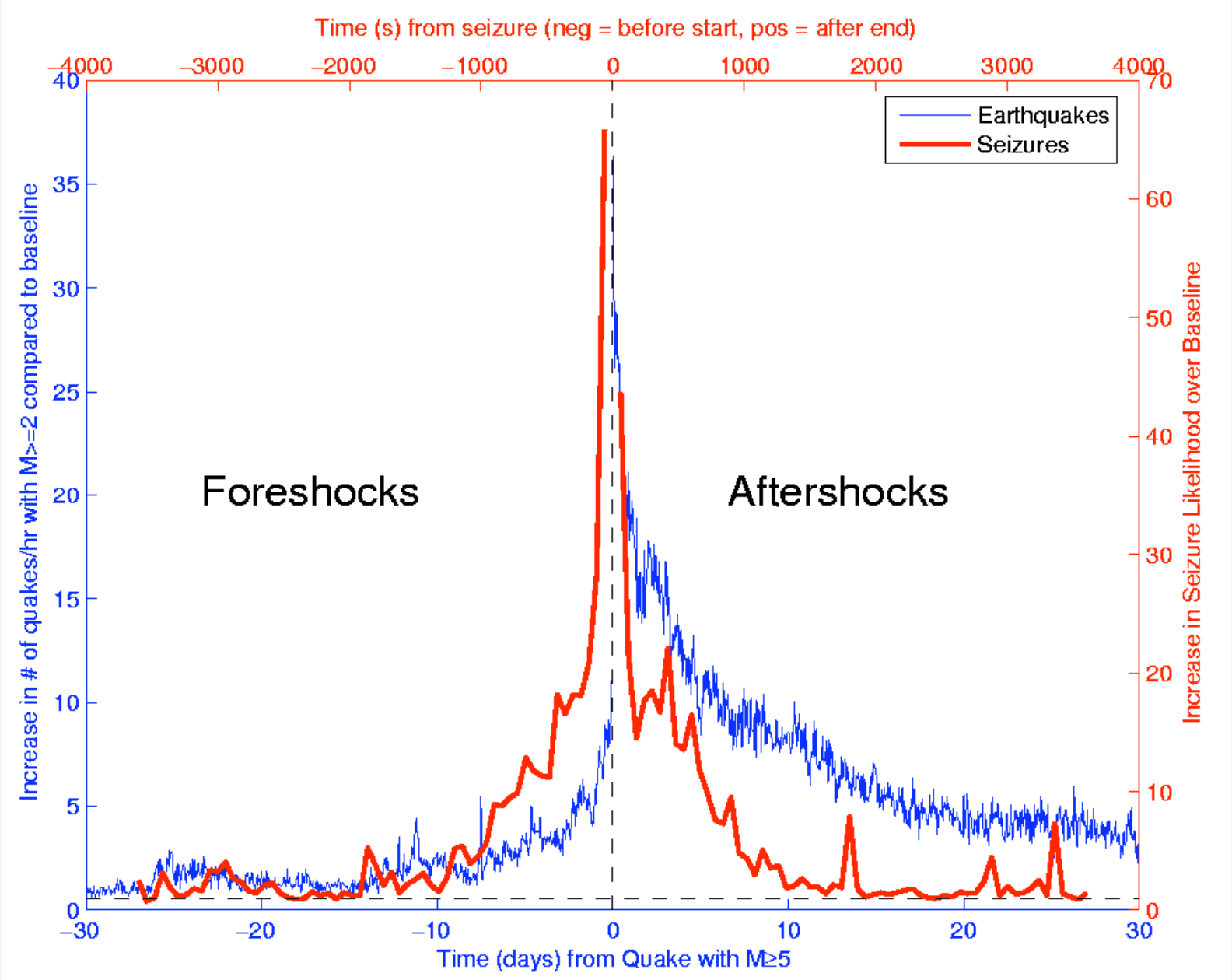
with Ivan Osorio – KUMC & FHS
Mark G. Frei - FHS
John Milton -The Claremont Colleges

(arxiv.org/abs/0712.3929)

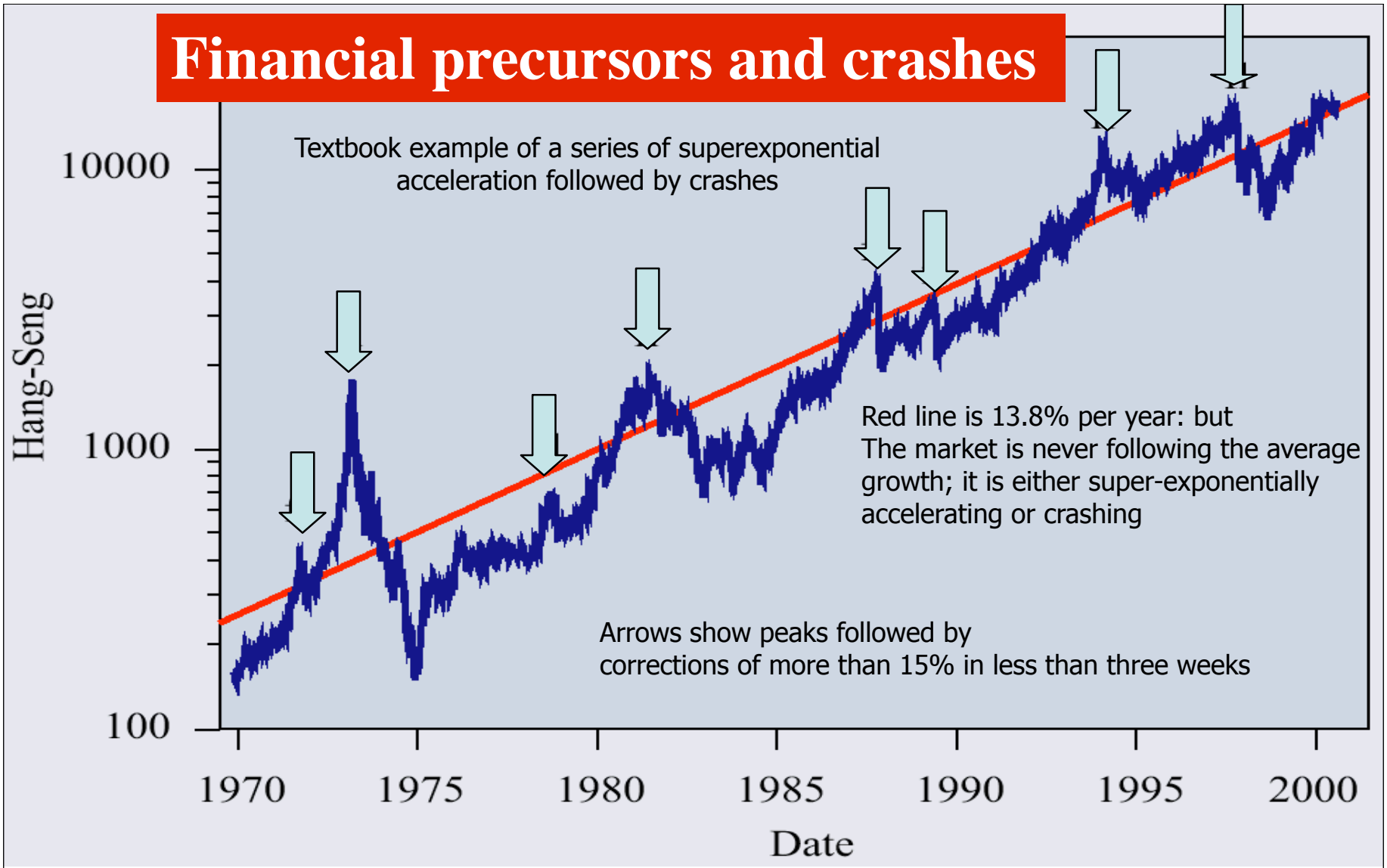


Key: L=Left
R=Right
A=Anterior
M=Mesial
P=Posterior
D=Depth
T=Temporal
F=Frontal

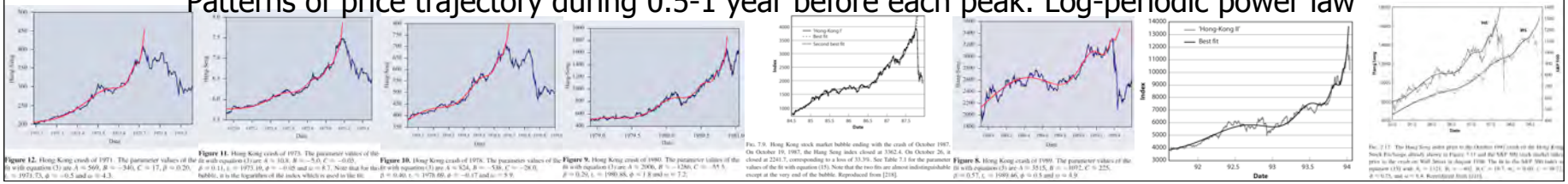
Omori law: Direct and Inverse



Financial precursors and crashes



Patterns of price trajectory during 0.5-1 year before each peak: Log-periodic power law



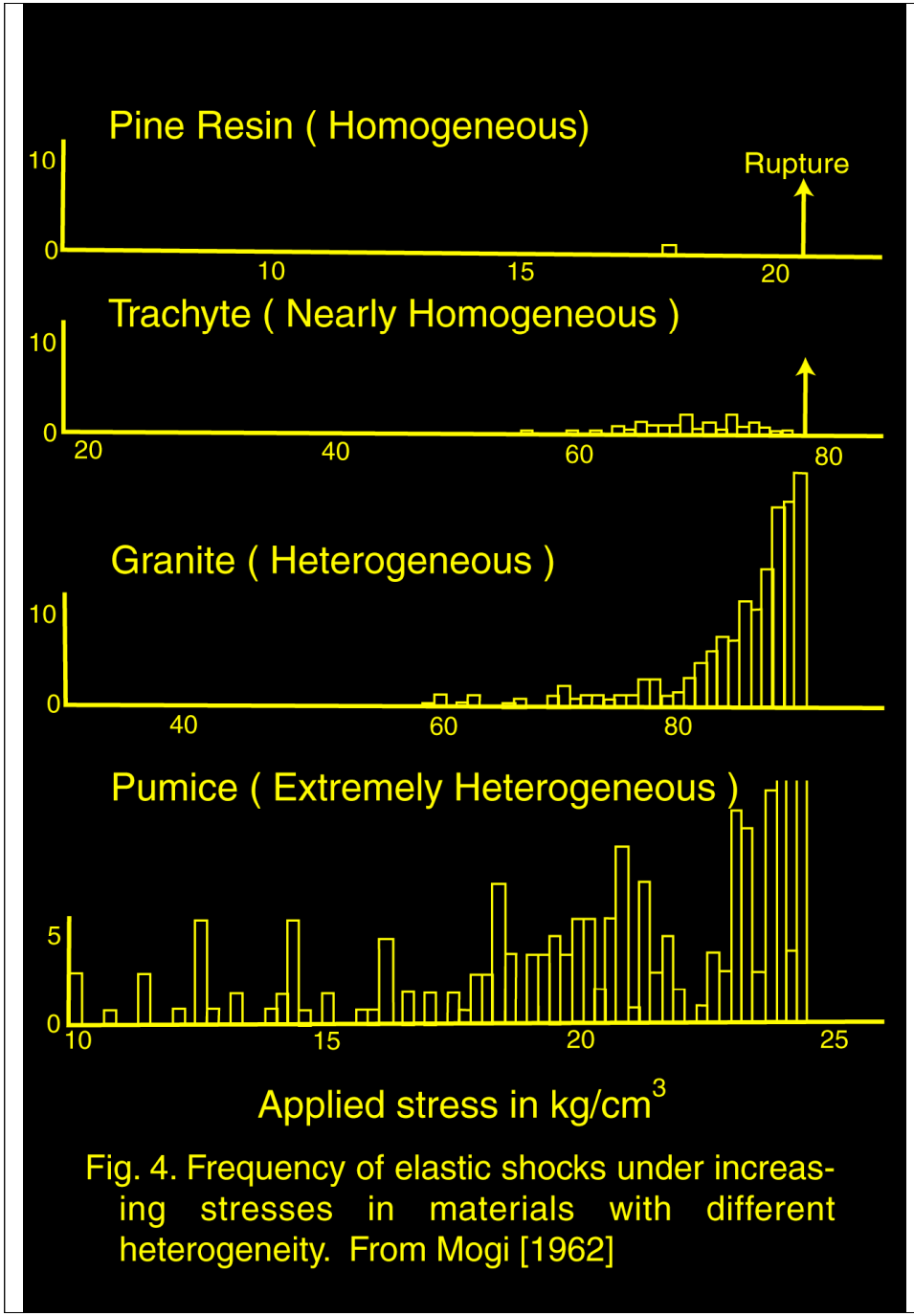
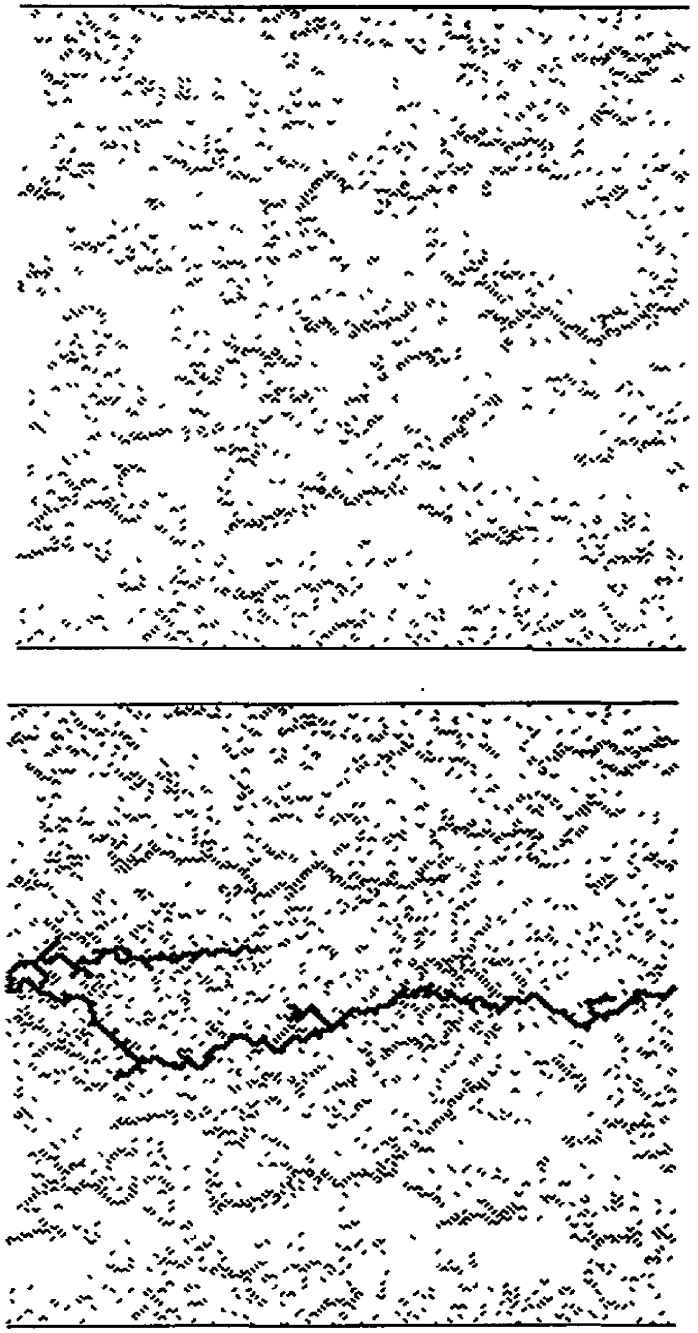
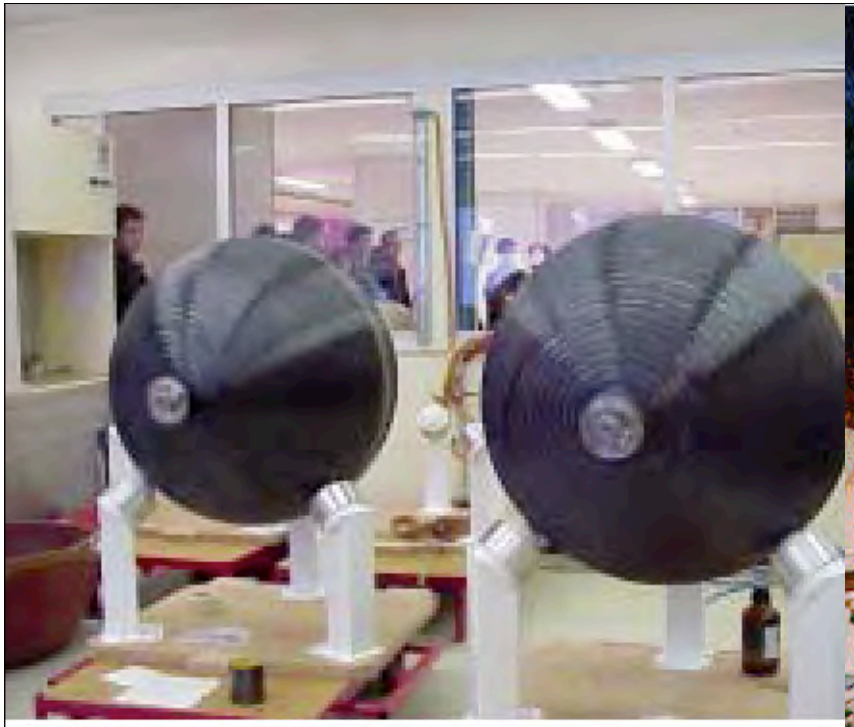


Fig. 4. Frequency of elastic shocks under increasing stresses in materials with different heterogeneity. From Mogi [1962]





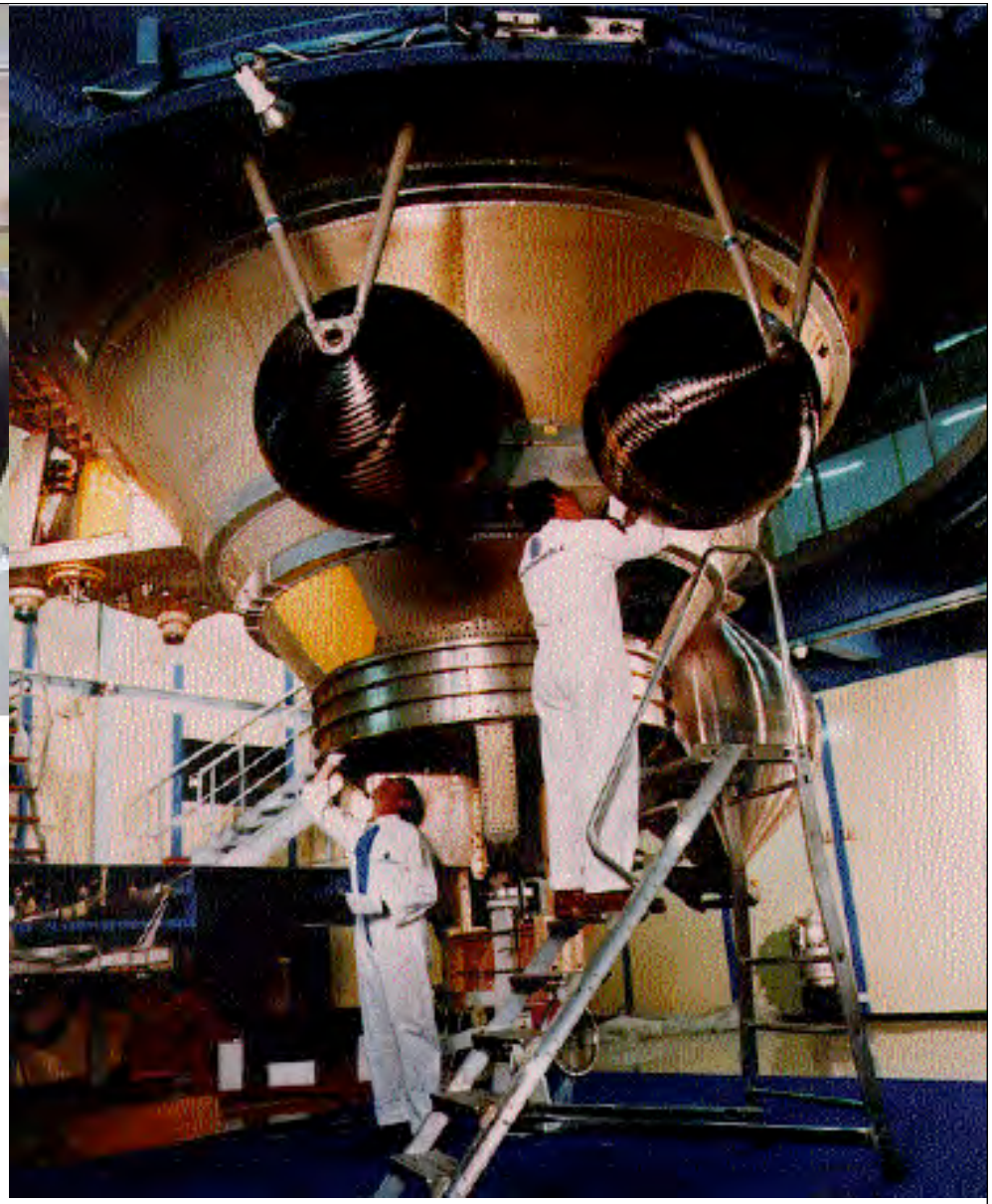


Figure 1: Ariane 5 composite high pressure tanks

Our prediction system is now used in the industrial phase as the standard testing procedure.

EADS LAUNCH VEHICLES

J.-C. Anifrani, C. Le Floc'h, D. Sornette and B. Souillard
"Universal Log-periodic correction to renormalization group scaling for rupture stress prediction from acoustic emissions", J.Phys.I France 5, n°6, 631-638 (1995)

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(useless?) IMPOSSIBILITY THEOREM

Algorithmic complexity theory: most complex systems have been proved to be computationally irreducible, i.e. the only way to decide about their evolution is to actually let them evolve in time.

The future time evolution of most complex systems appears inherently unpredictable.

BUT, Physics and engineering works and is not hampered by computational irreducibility because we only ask for answers at some coarse-grained level.

Computational Irreducibility and the Predictability of Complex Physical Systems

Navot Israeli and Nigel Goldenfeld

PhysRevLett.92.074105 (2004)

256 nearest neighbor 1D cellular automata (Wolfram)

Class 3 → Class 1

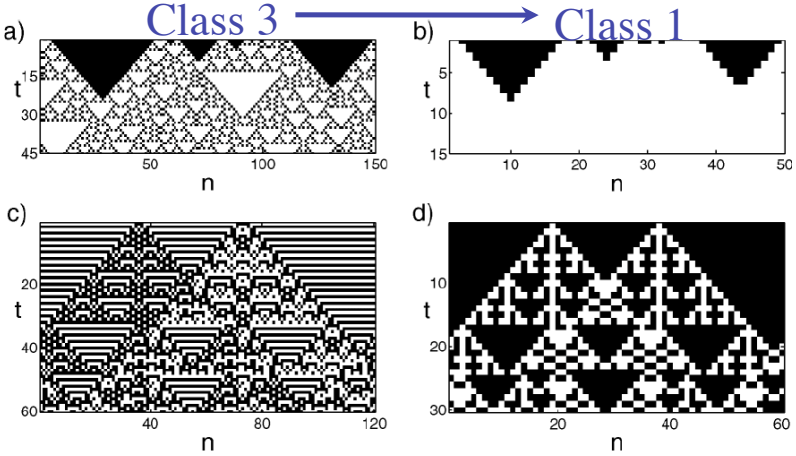

FIG. 1. Examples of coarse-graining transitions. (a) and (b) show coarse-graining rule 146 by rule 128. (a) shows results of running rule 146. The top line is the initial condition and time progress from top to bottom. (b) shows the results of running rule 128 with the coarse-grained initial condition from (a). (c) and (d) show coarse-graining rule 105 by rule 150. (c) shows rule 105 and (d) shows rule 150.

$$C(f_A^{T\cdot t}a(0)) = f_B^t C(a(0)).$$

Namely, running the original CA for Tt time steps and then coarse graining is equivalent to coarse graining the initial condition and then running the modified CA t time steps. The constant T is a time scale associated with the coarse graining.

240 coarse-grainable

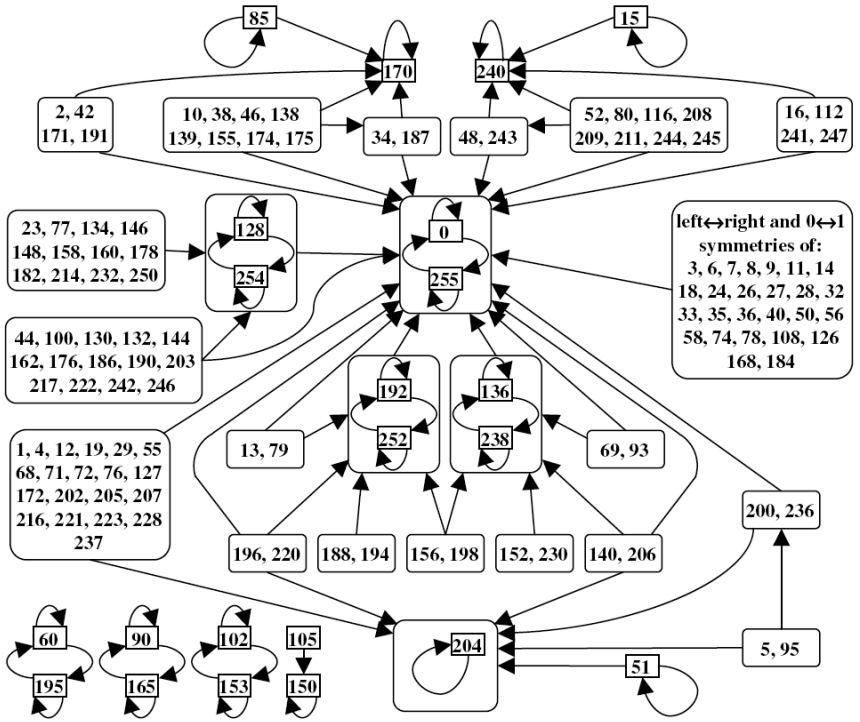

FIG. 2. Coarse-graining transitions within the family of 256 elementary CA. Only transitions with a cell block size $N = 2$, 3, and 4 are shown. An arrow indicates that the origin rules can be coarse grained by the target rules and may correspond to several choices of N and P.

N-block approach with N=2, 3 or 4

Coarse-graining rule 110: CIR => C1