Black Swans, Dragons-Kings and Prediction

Didier SORNETTE

ETH Zurich

Professor of Entrepreneurial Risks

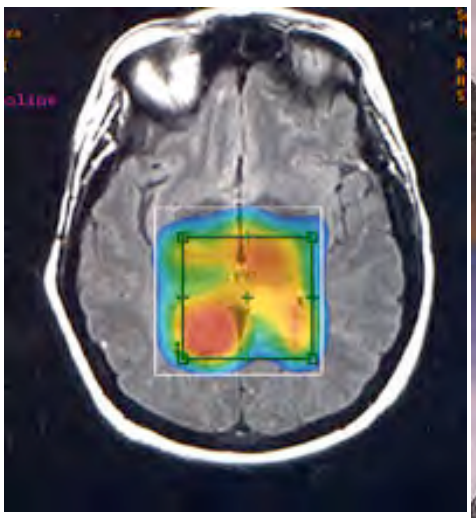
Professor of Geophysics associated with the Department of Earth Sciences (D-ERWD), ETH Zurich

Professor of Physics associated with the Department of Physics (D-PHYS), ETH Zurich

Professor of Finance at the Swiss Finance Institute

Director of the Financial Crisis Observatory

co-founder of the Competence Center for Coping with Crises in Socio-Economic Systems, ETH Zurich (http://www.ccss.ethz.ch/)



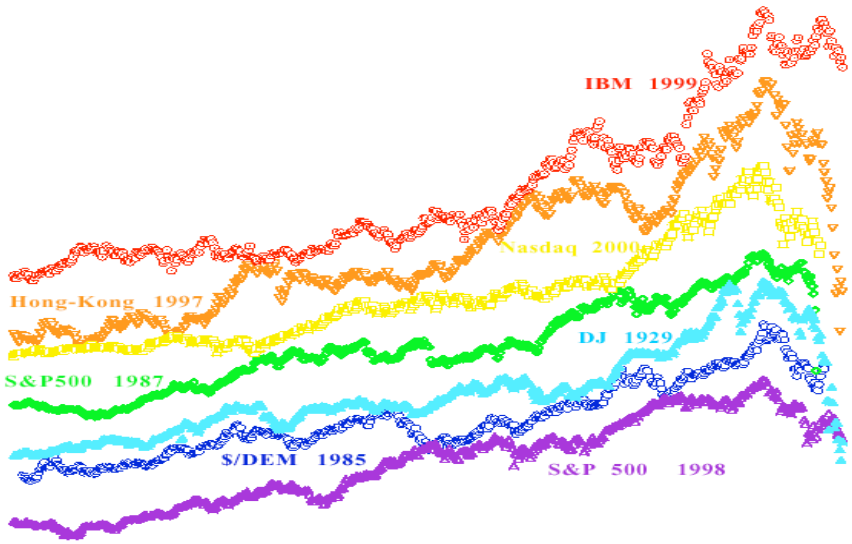
www.er.ethz.ch

EXTREME EVENTS in Natural SYSTEMS

- Earthquakes
- Volcanic eruptions
- Hurricanes and tornadoes
- Landslides, mountain collapses
- Avalanches, glacier collapses
- Lightning strikes
- Meteorites, asteroid impacts
- Catastrophic events of environmental degradations

EXTREME EVENTS in SOCIO-ECONOMIC SYSTEMS

- Failure of engineering structures
- Crashes in the stock markets
- Social unrests leading to large scale strikes and upheavals
- Economic recessions on regional and global scales
- Power blackouts
- Traffic gridlocks
- Social epidemics
- **Block-busters**
- **Discoveries-innovations**
- **Social groups, cities, firms...**
- **Nations**
- Religions...



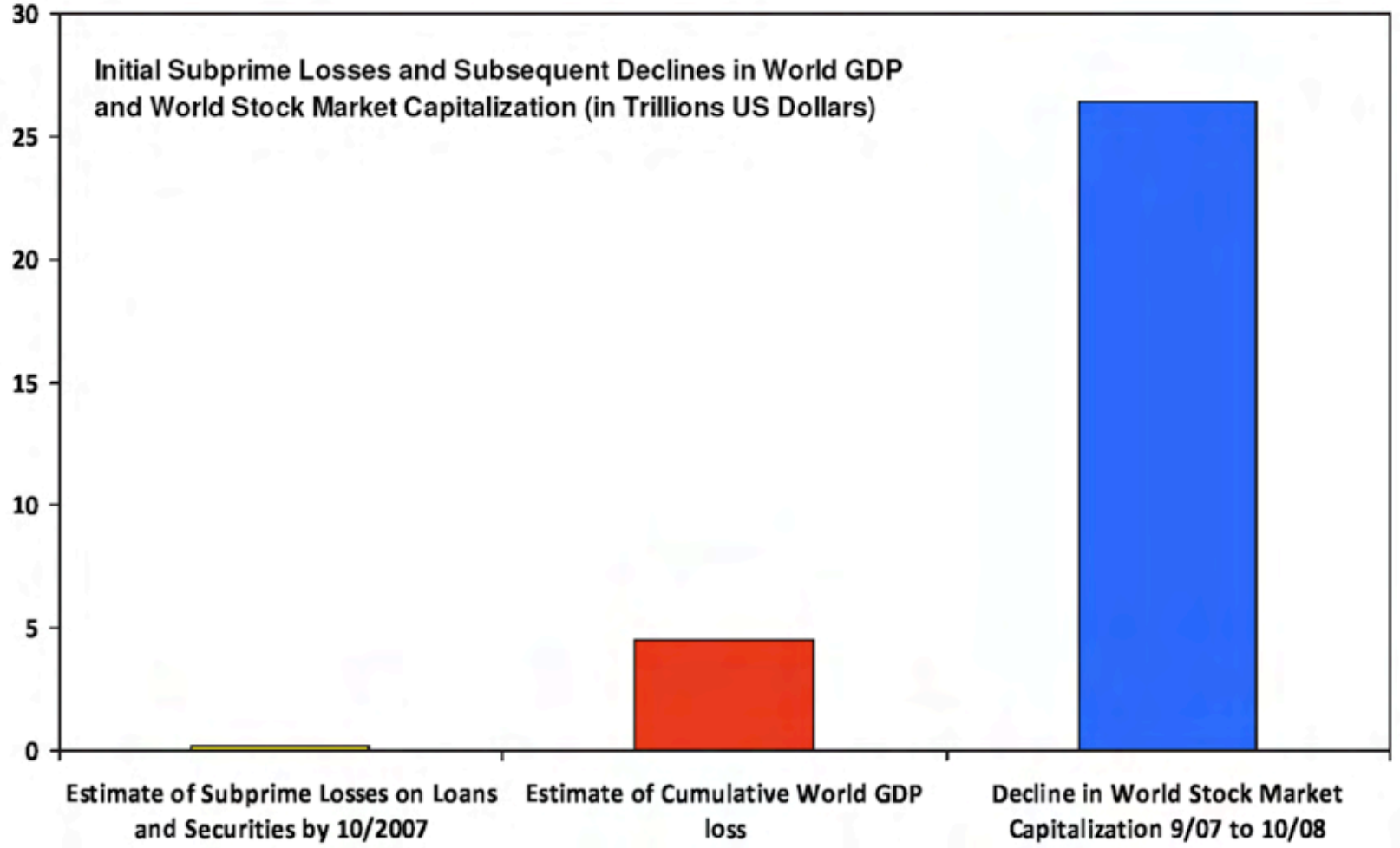
Extreme events are epoch changing

in the physical structure and in the mental spaces

- Droughts and the collapse of the Mayas (760-930 CE)... and many others...
- French revolution (1789) and the formation of Nation states
- Great depression and Glass-Steagall act
- Crash of 19 Oct. 1987 and volatility smile (crash risk)
- Enron and Worldcom accounting scandals and Sarbanes-Oxley (2002)
- Great Recession 2007-2009: consequences to be seen...

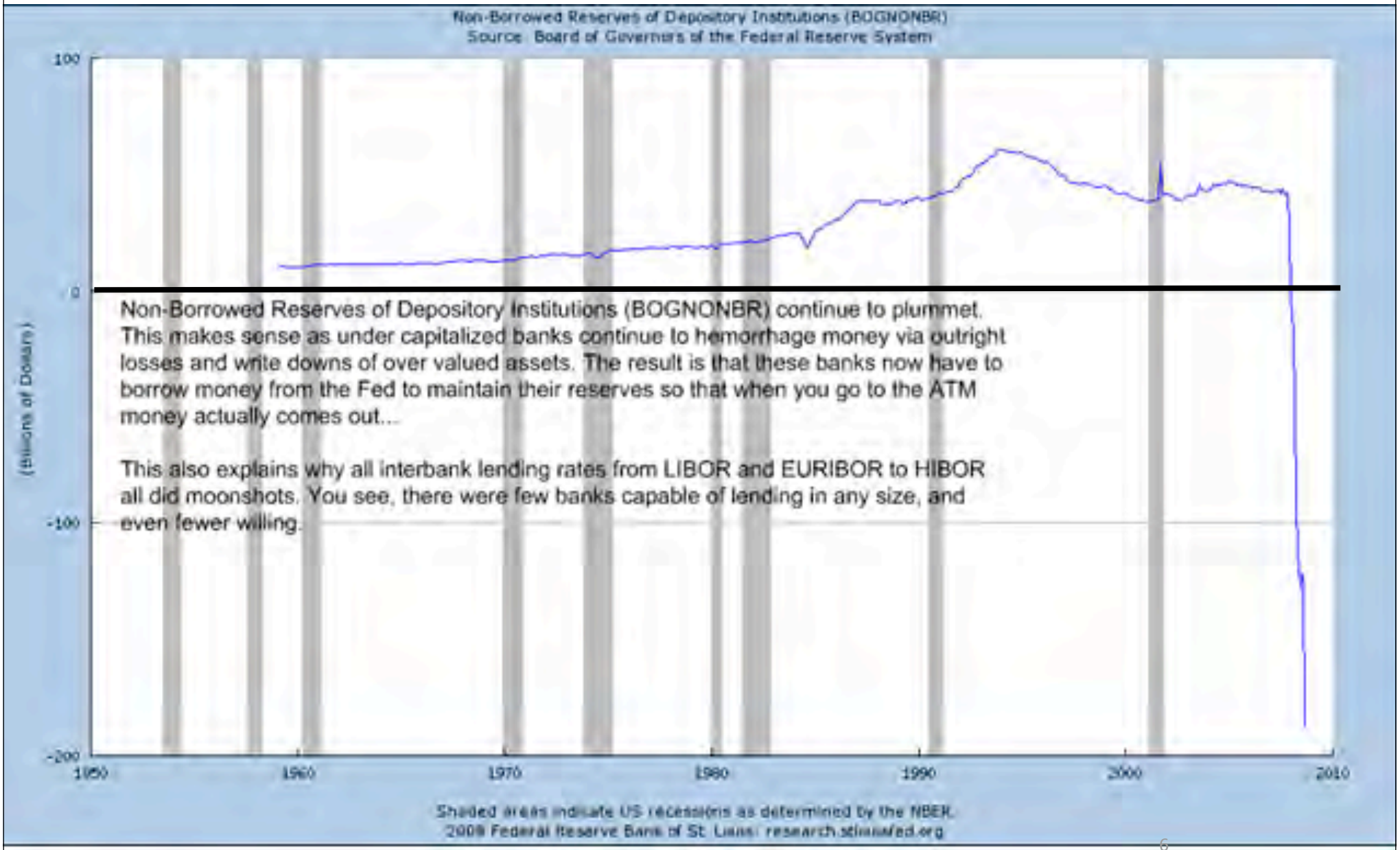
The Paradox of the 2007-20XX Crisis

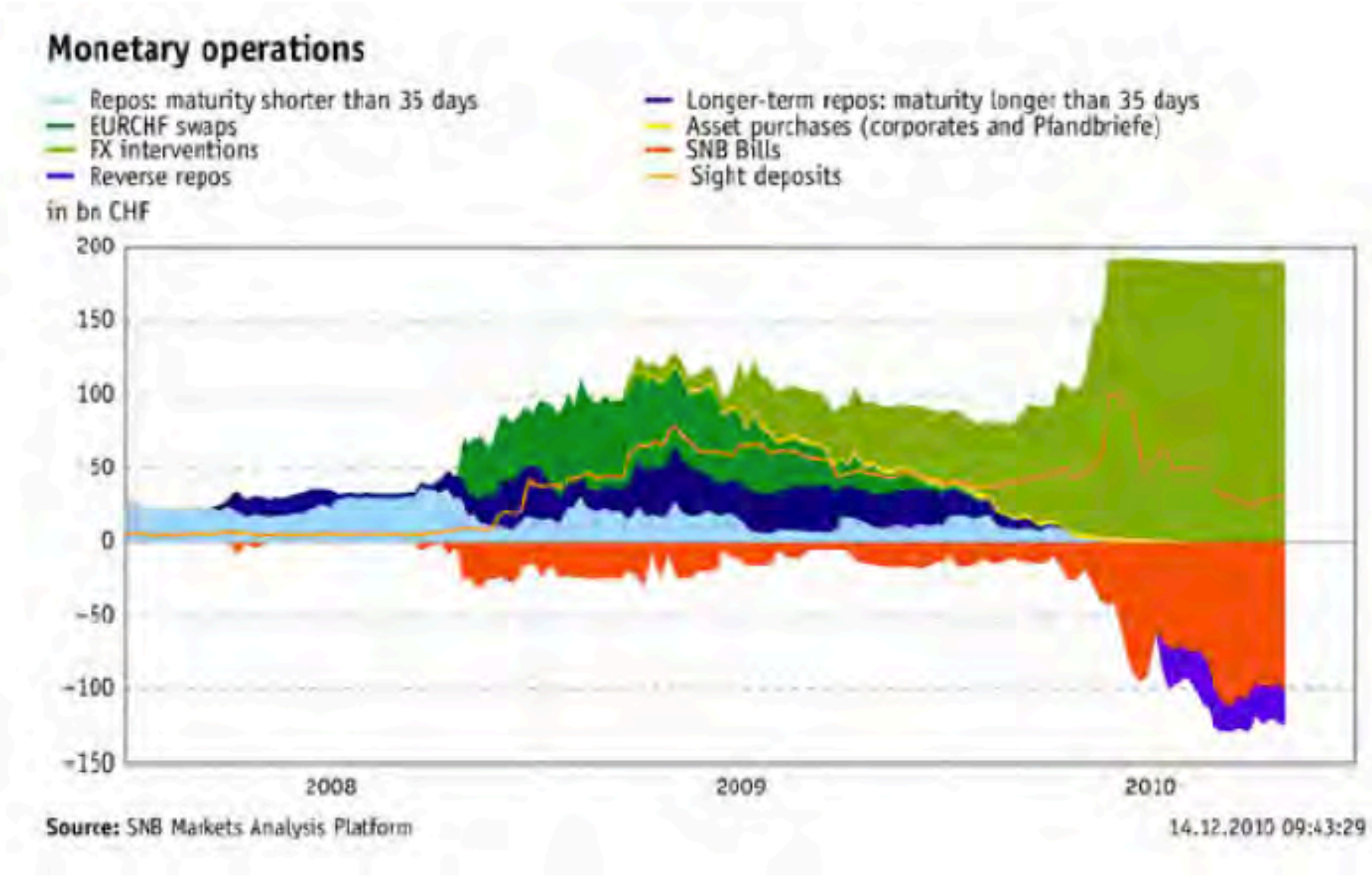
(trillions of US$)



Source: IMF Global Financial Stability Report; World Economic Outlook November update and estimates; World Federation of Exchanges.

2008 FINANCIAL CRISIS

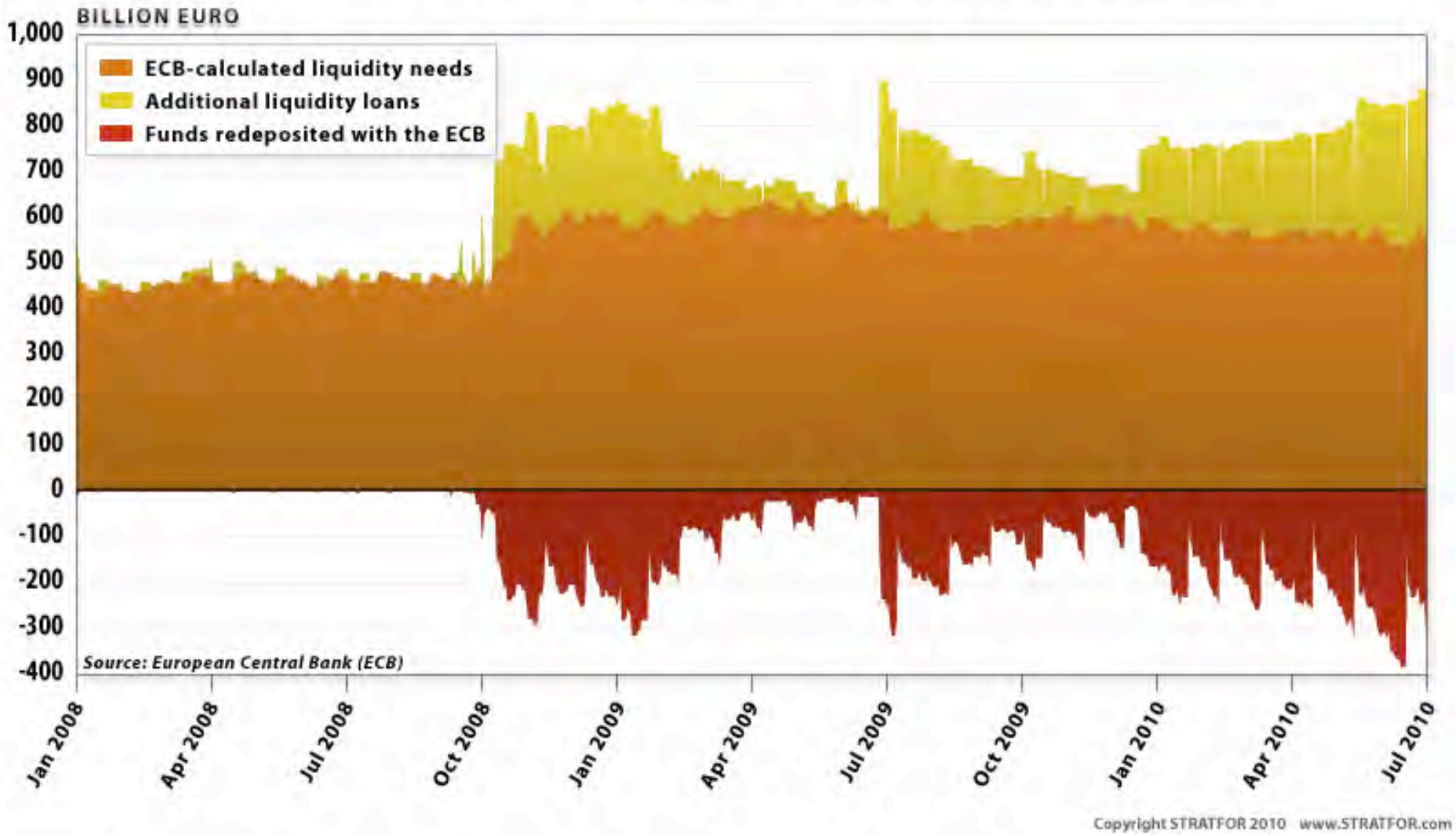




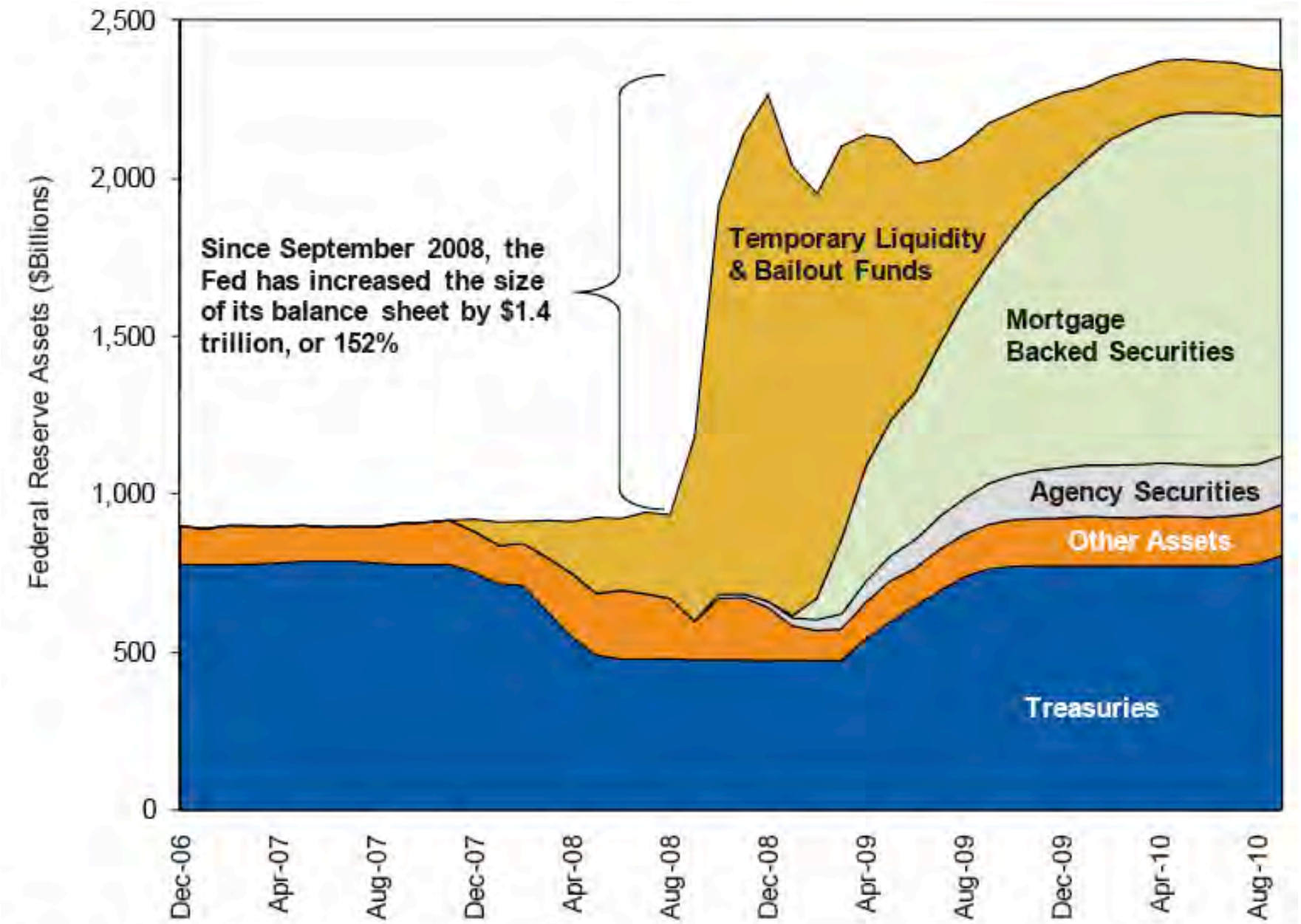
Jean-Pierre Danthine: Swiss monetary policy and Target2-Securities

Introductory remarks by Mr Jean-Pierre Danthine, Member of the Governing Board of the Swiss National Bank, at the end-of-year media news conference, Zurich, 16 December 2010.

EUROZONE BANKS: LIQUIDITY SUPPLY AND DEMAND



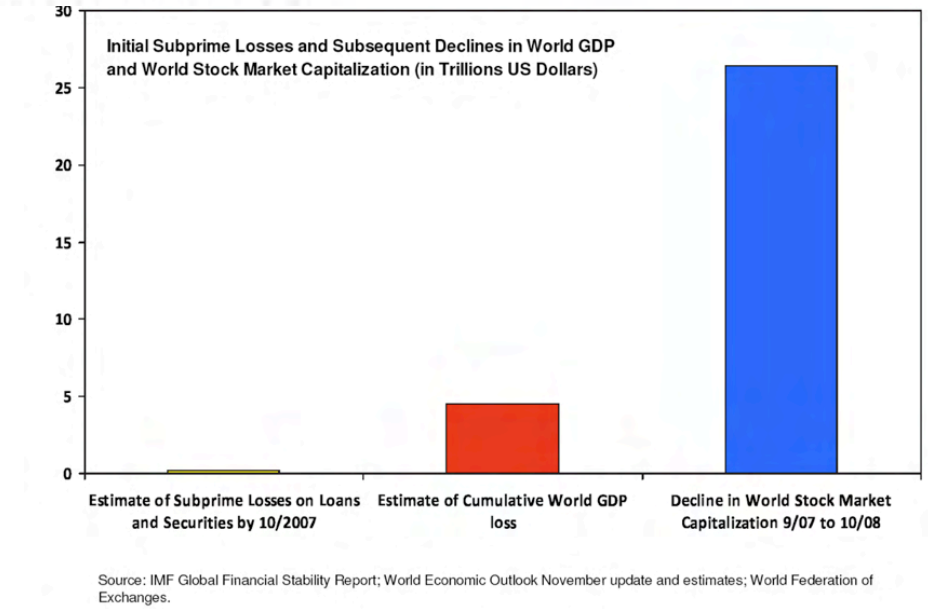
Federal Reserve balance sheet



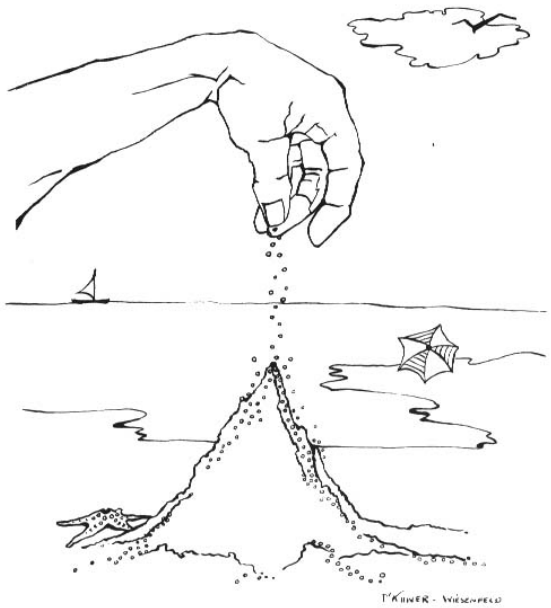
Source: Federal Reserve; as of 9/30/2010

Black Swan story

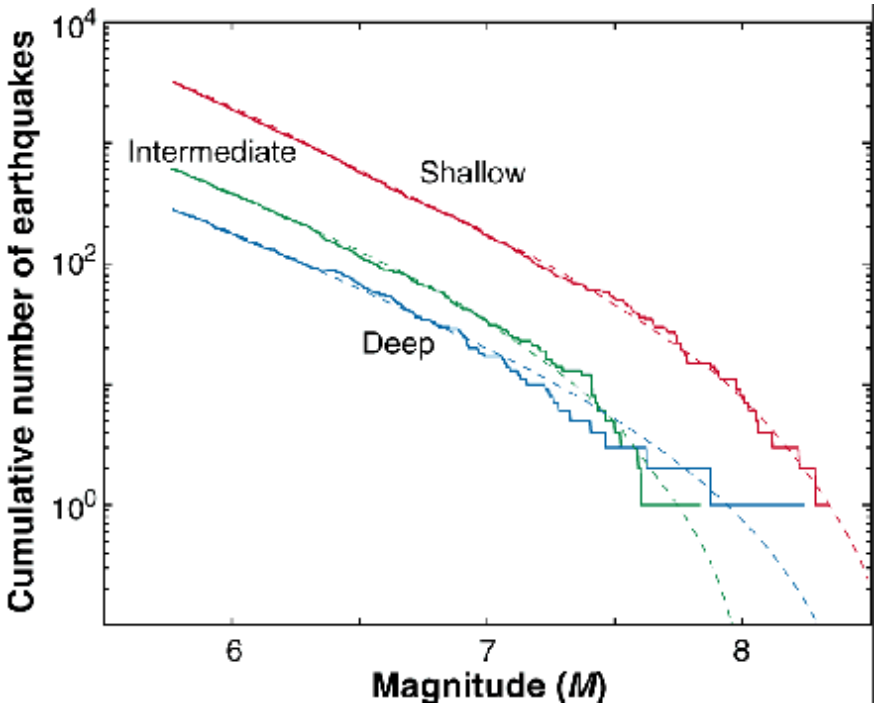
- Unknown unknowable event
  - ★ cannot be diagnosed in advance, cannot be quantified, no predictability
- No responsability ("wrath of God")
- One unique strategy: long put options and insurance



Self-organized criticality

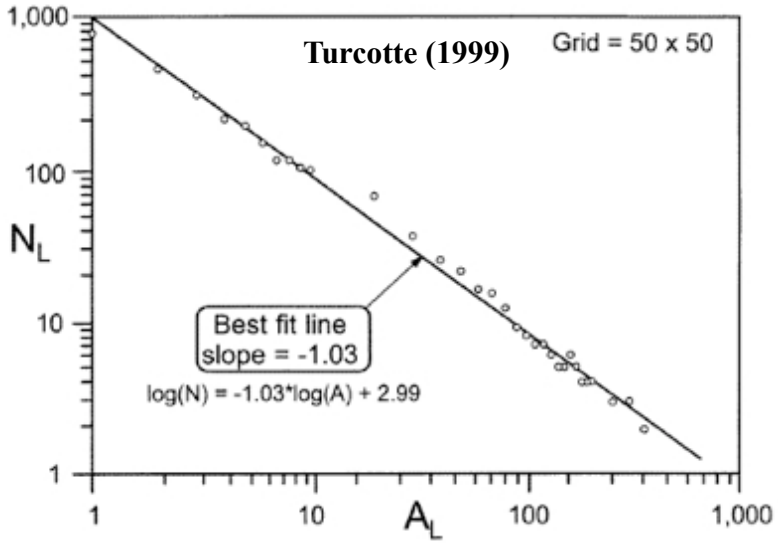


(Bak, Tang, Wiesenfeld, 1987)

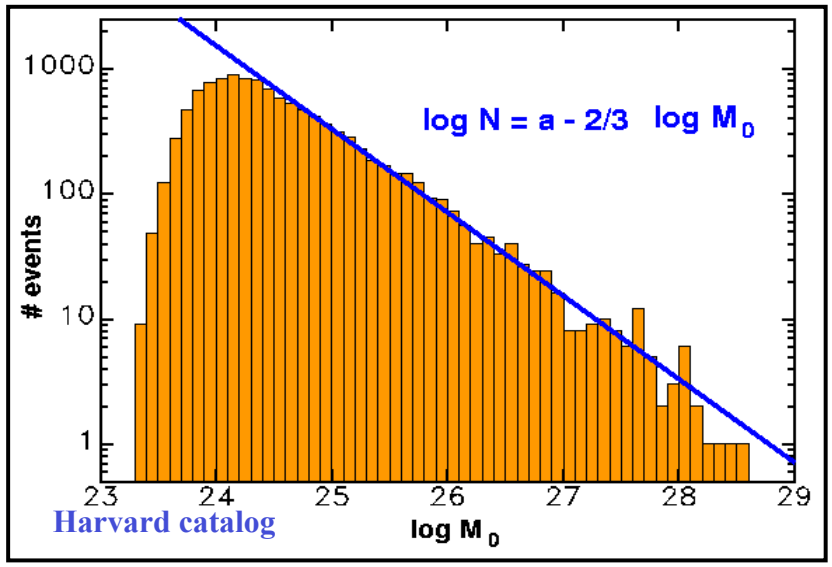


Earthquakes Cannot Be Predicted

Robert J. Geller, David D. Jackson, Yan Y. Kagan, Francesco Mulargia
Science 275, 1616-1617 (1997)

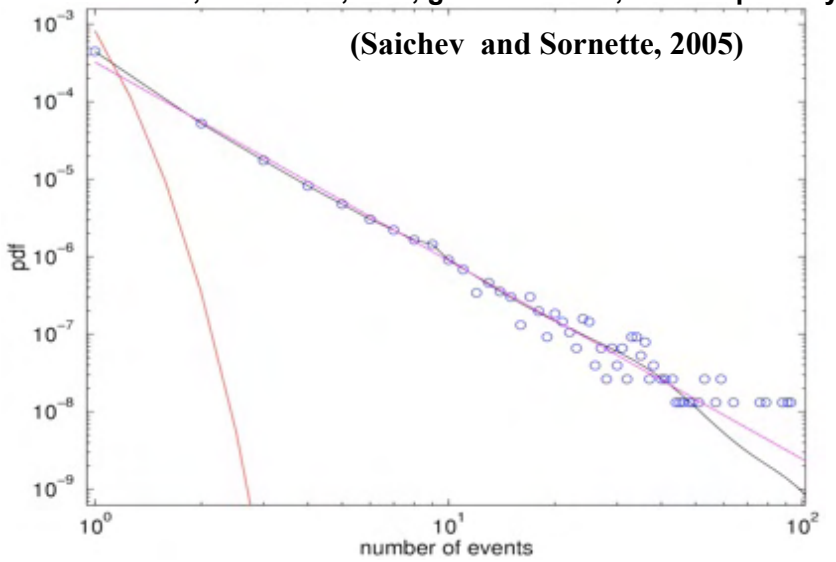


Heavy tails in pdf of earthquakes

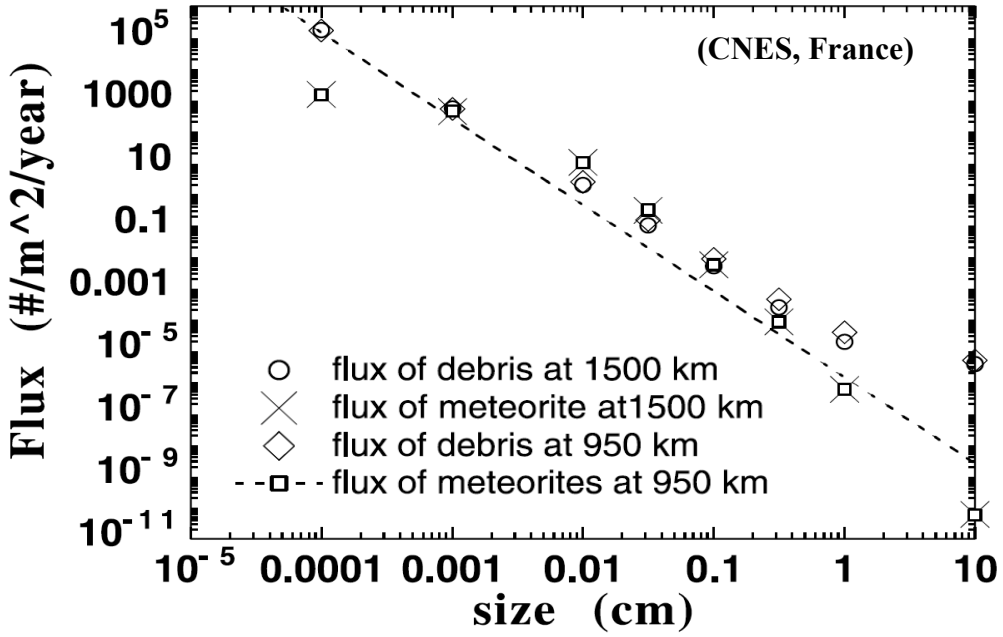


Heavy tails in pdf of seismic rates

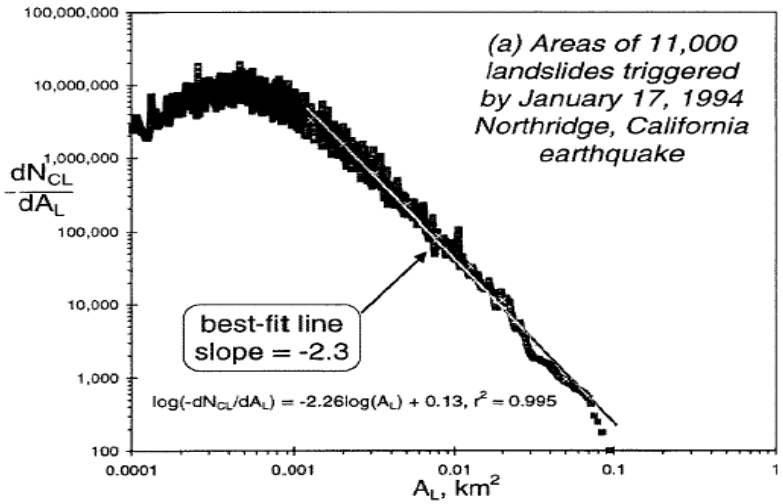
SCEC, 1985-2003, m≥2, grid of 5x5 km, time step=1 day



Heavy tails in ruptures



Heavy tails in pdf of rock falls, Landslides, mountain collapses



Turcotte (1999)

Heavy tails in pdf of forest fires

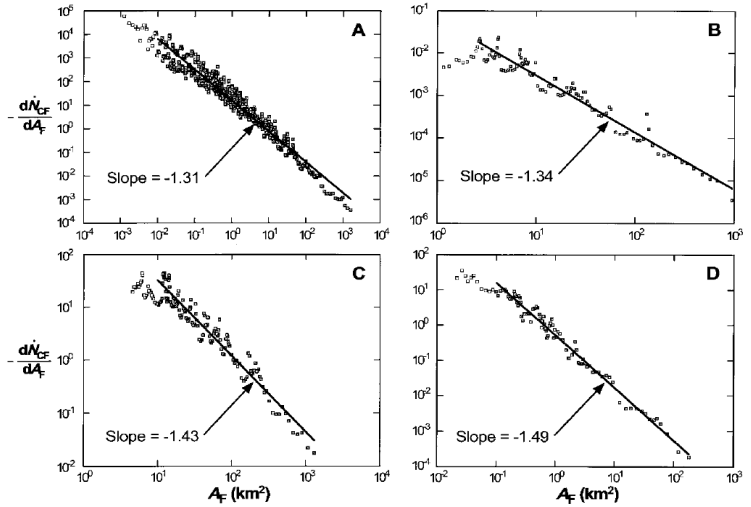
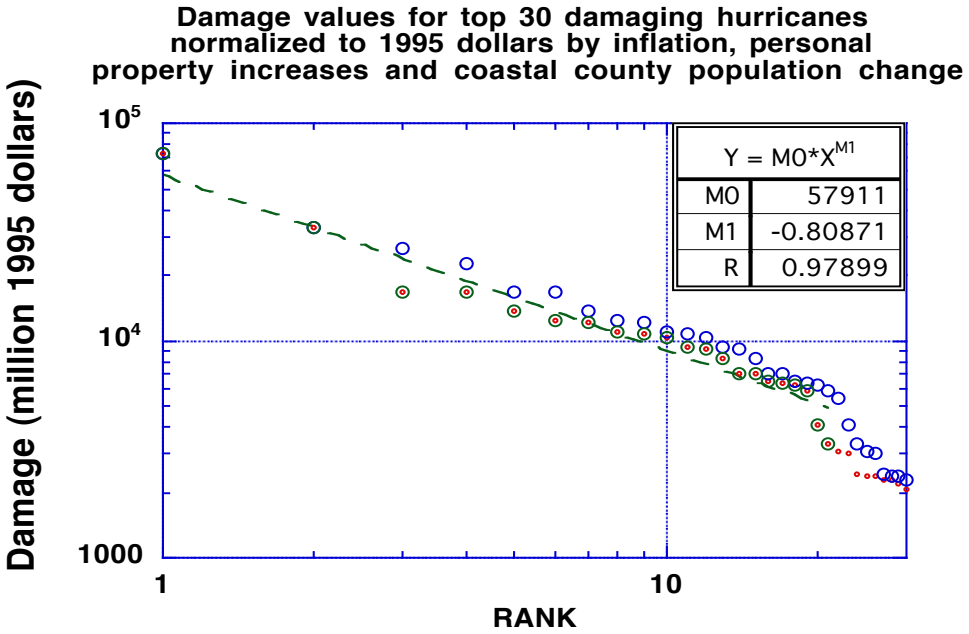


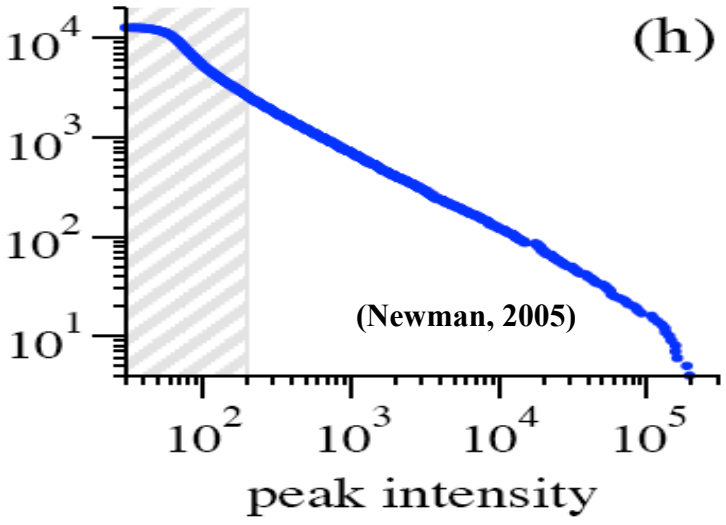
Fig. 2. Noncumulative frequency-area distributions for actual forest fires and wildfires in the United States and Australia: (**A**) 4284 fires on U.S. Fish and Wildlife Service lands (1986–1995) (*9*), (**B**) 120 fires in the western United States (1150–1960) (*10*), (**C**) 164 fires in Alaskan boreal forests (1990–1991) (*11*), and (**D**) 298 fires in the ACT (1926–1991) (*12*). For each data set, the noncumulative number of fires per year ($-d\dot{N}_{CF}/dA_F$) with area (A_F) is given as a function of A_F (*13*). In each case, a reasonably good correlation over many decades of A_F is obtained by using the power-law relation (Eq. 1) with $\alpha = 1.31$ to 1.49; $-\alpha$ is the slope of the best-fit line in log-log space and is shown for each data set.

Malamud et al., Science 281 (1998)

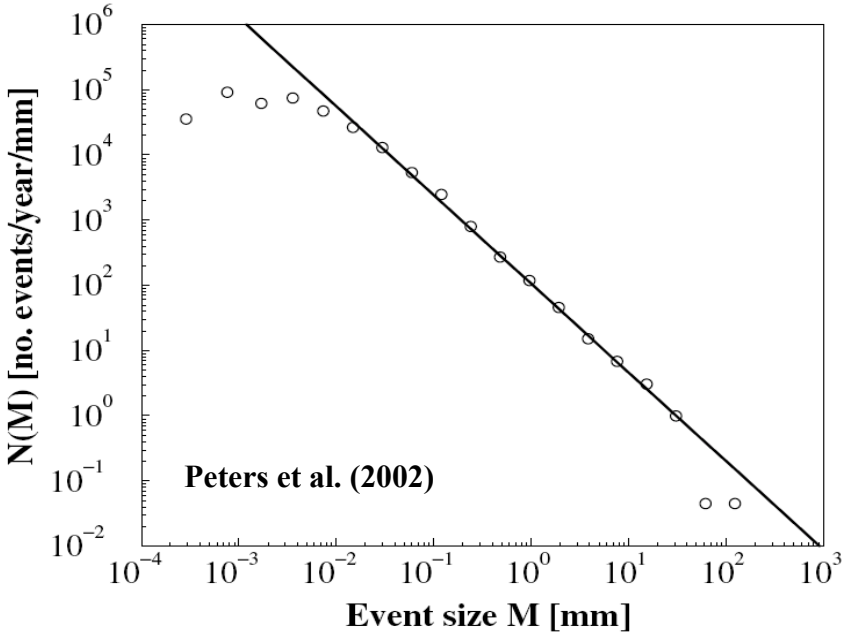
Heavy tails in pdf of Hurricane losses



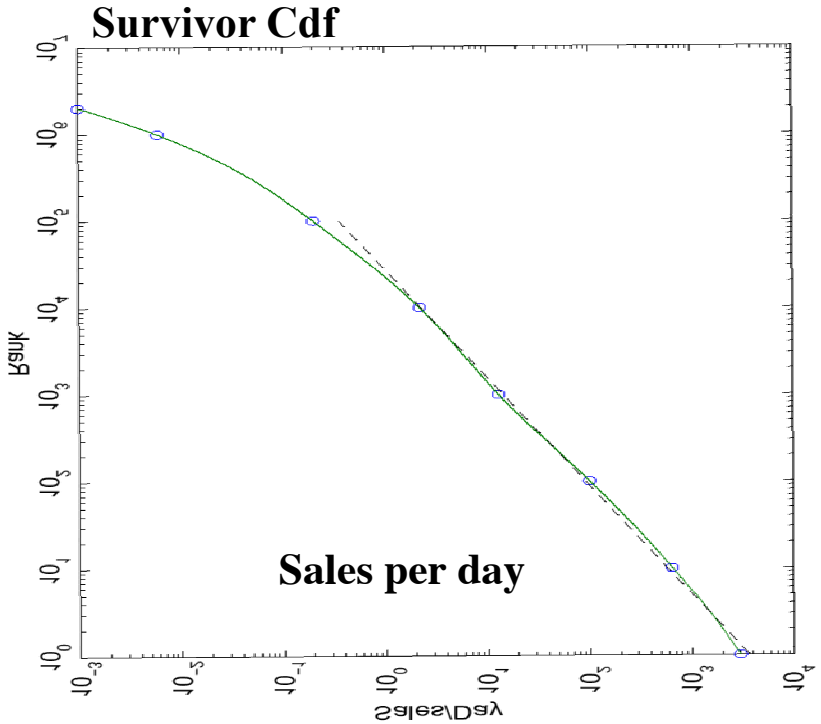
Heavy tails in pdf of Solar flares



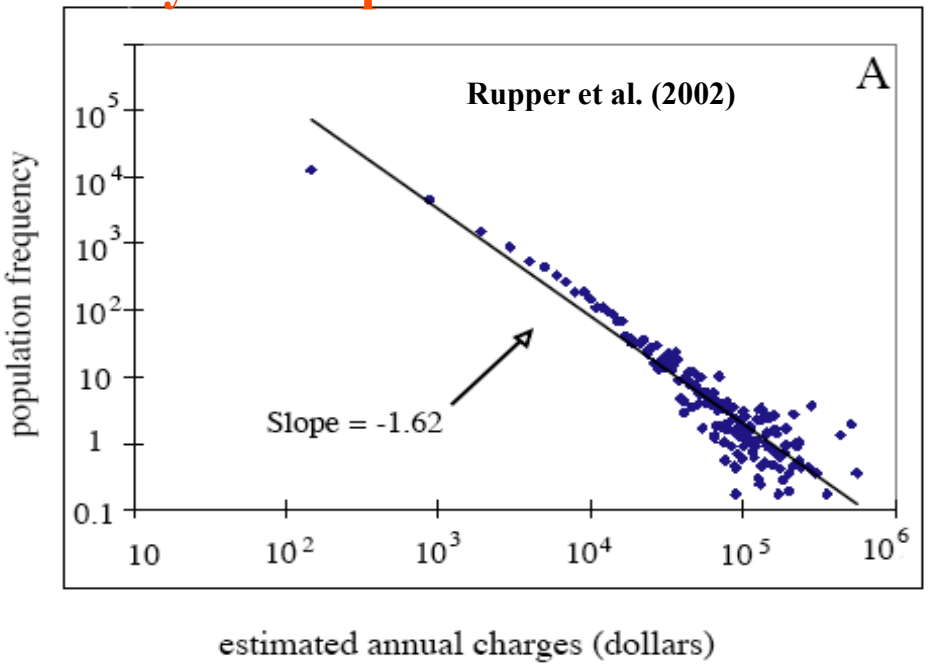
Heavy tails in pdf of rain events



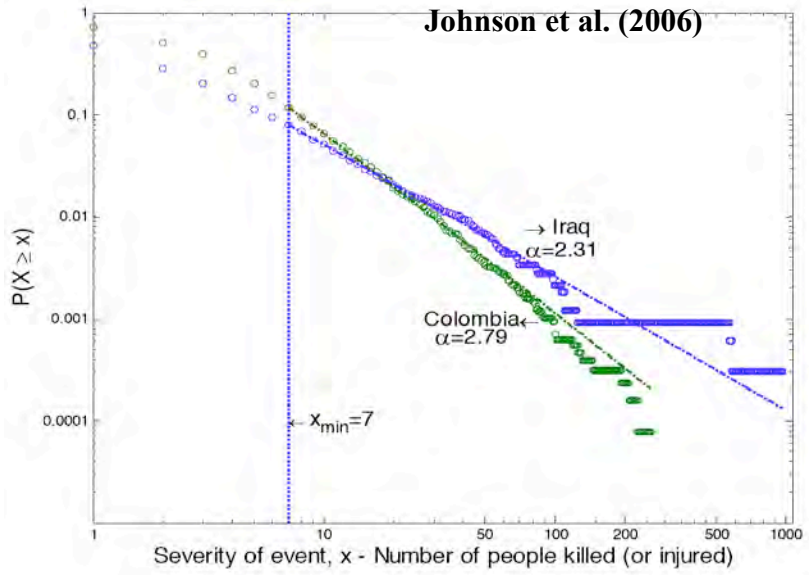
Heavy-tail of pdf of book sales



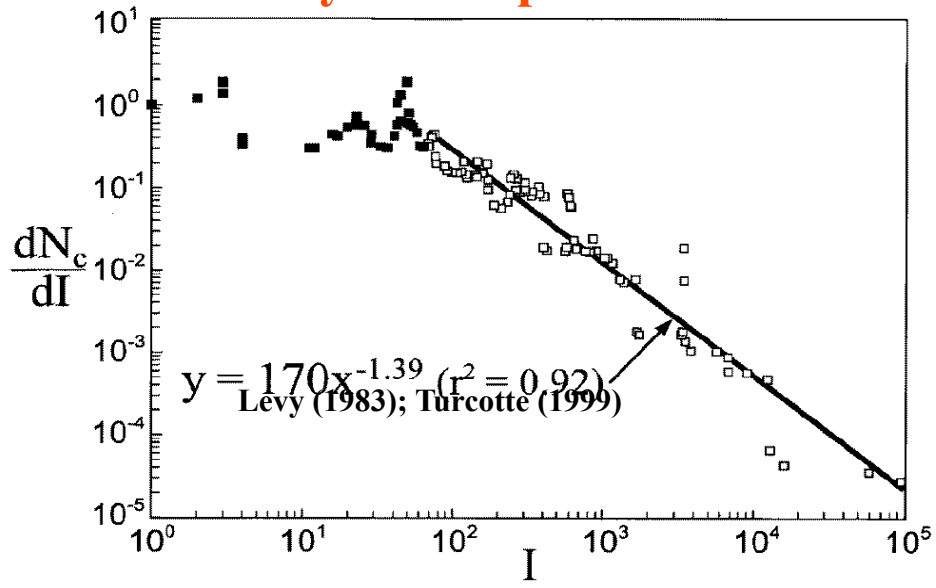
Heavy-tail of pdf of health care costs



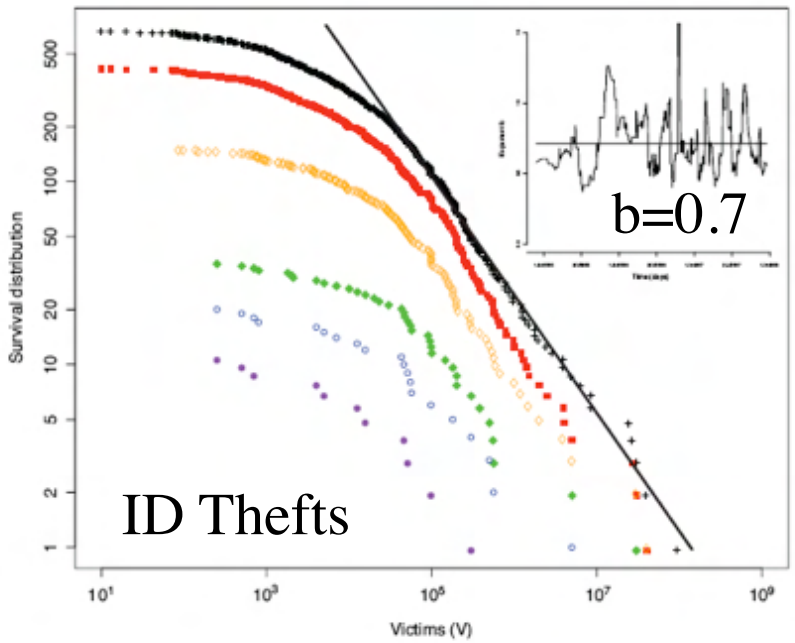
Heavy-tail of pdf of terrorist intensity



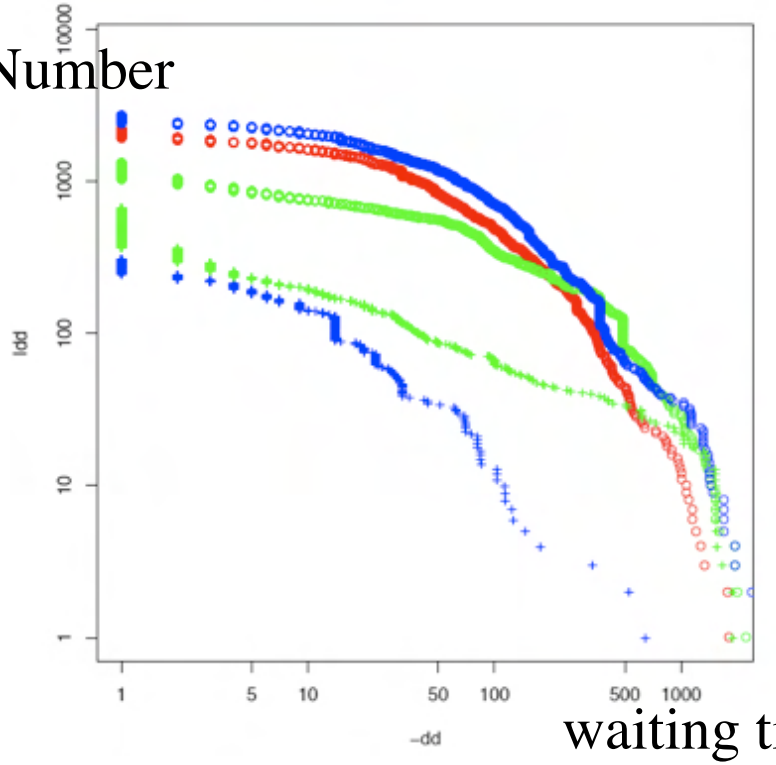
Heavy-tail of pdf of war sizes



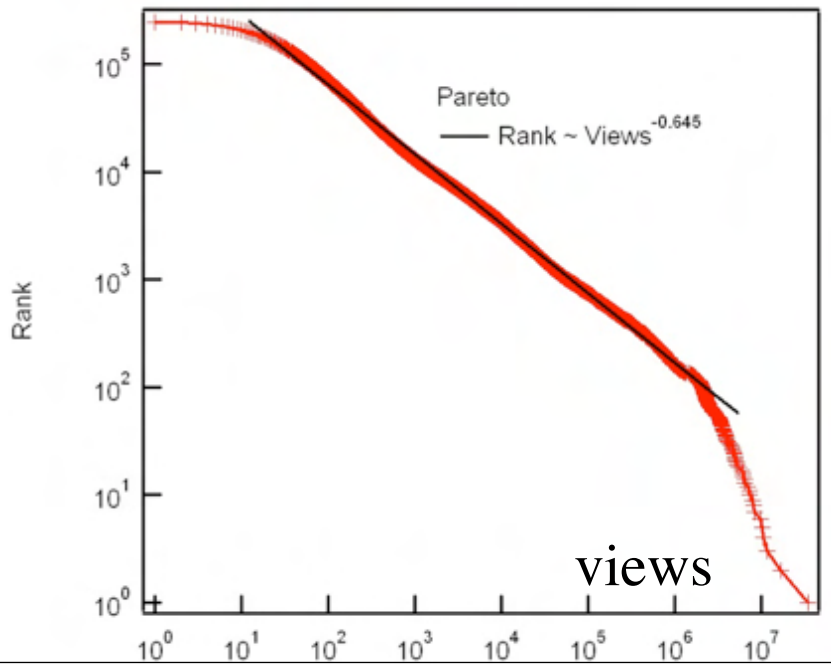
Heavy-tail of cdf of cyber risks



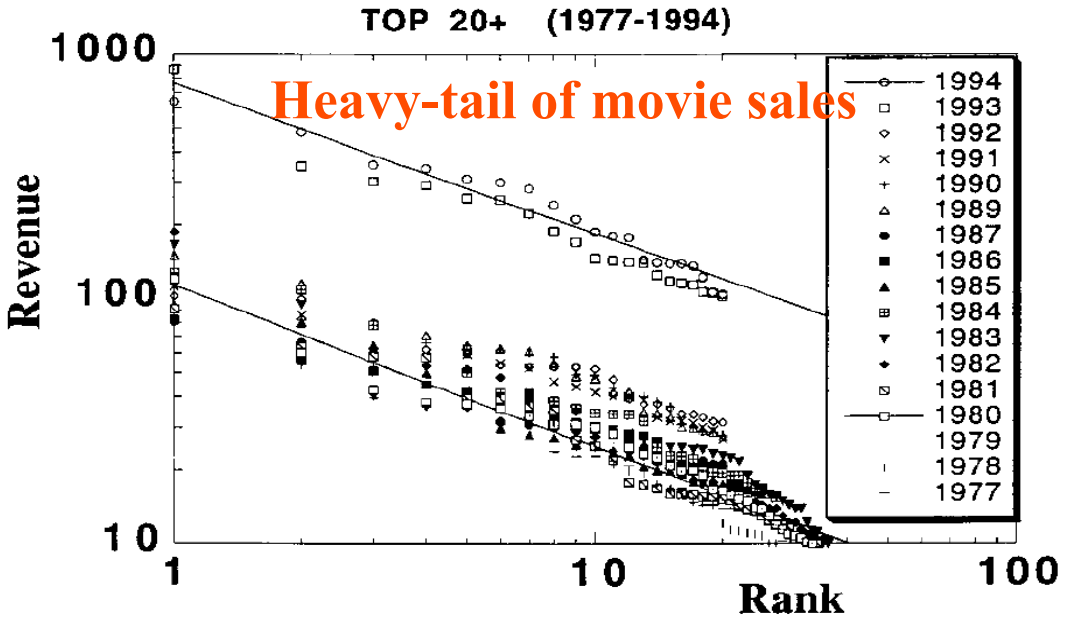
Software vulnerabilities



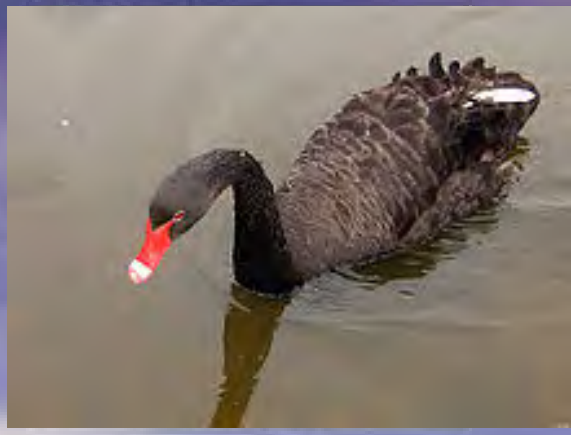
Heavy-tail of YouTube view counts



Heavy-tail of movie sales



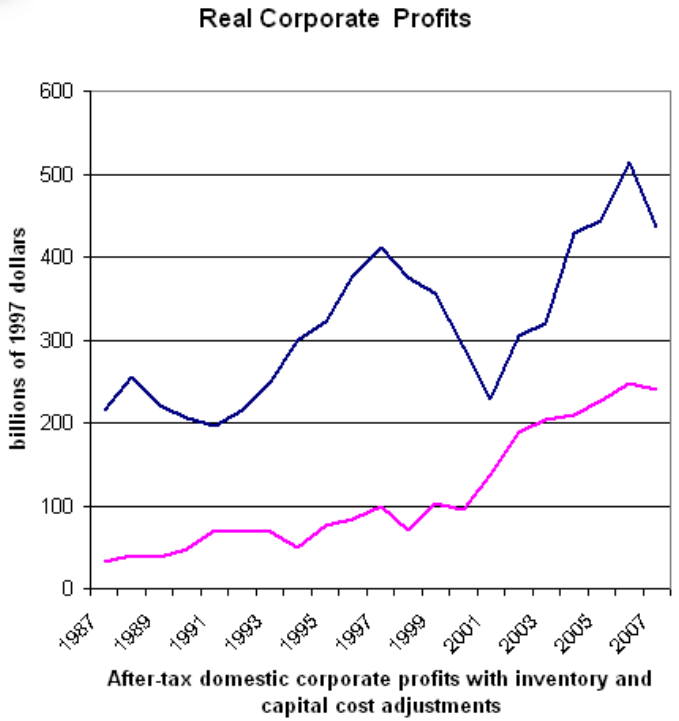
Crises are not black swans but "Dragon-kings"



Black Swan (*Cygnus atratus*)

Dragon-king hypothesis

- Most crises are "endogenous"
  - ★ can be diagnosed in advance, can be quantified, (some) predictability
- Moral hazard, conflict of interest, role of regulations
- Responsibility, accountability
- Strategic vs tactical time-dependent strategy
- Weak versus global signals



http://www.businessweek.com/the_thread/economicsunbound/archives/2009/03/a_bad_decade_fo.html

Beyond power laws: 7 examples of "Dragons"

Financial economics: Outliers and dragons in the distribution of financial drawdowns.

Population geography: Paris as the dragon-king in the Zipf distribution of French city sizes.

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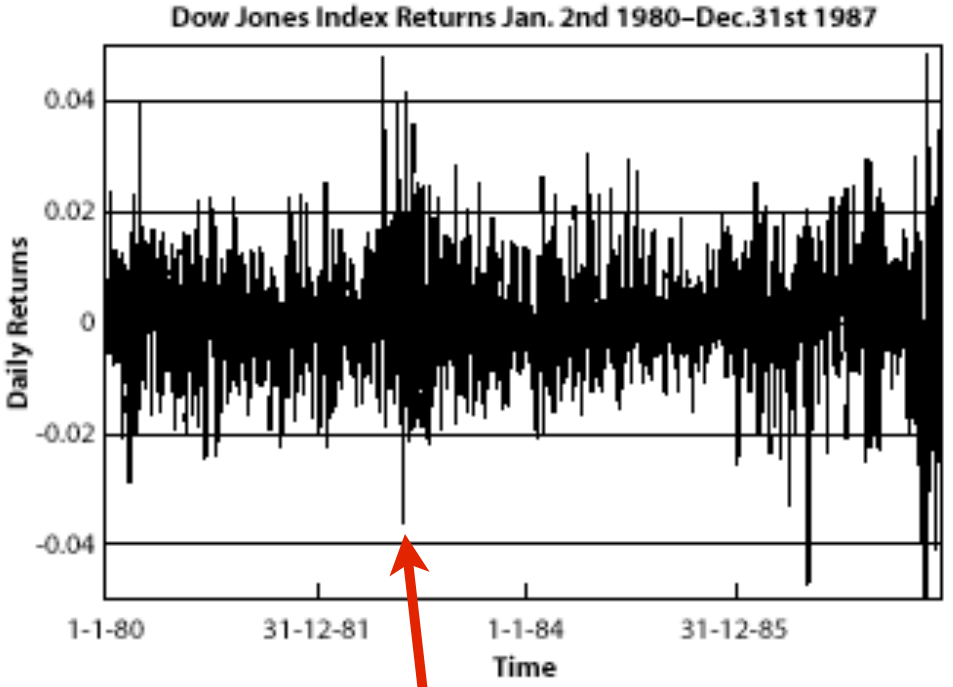
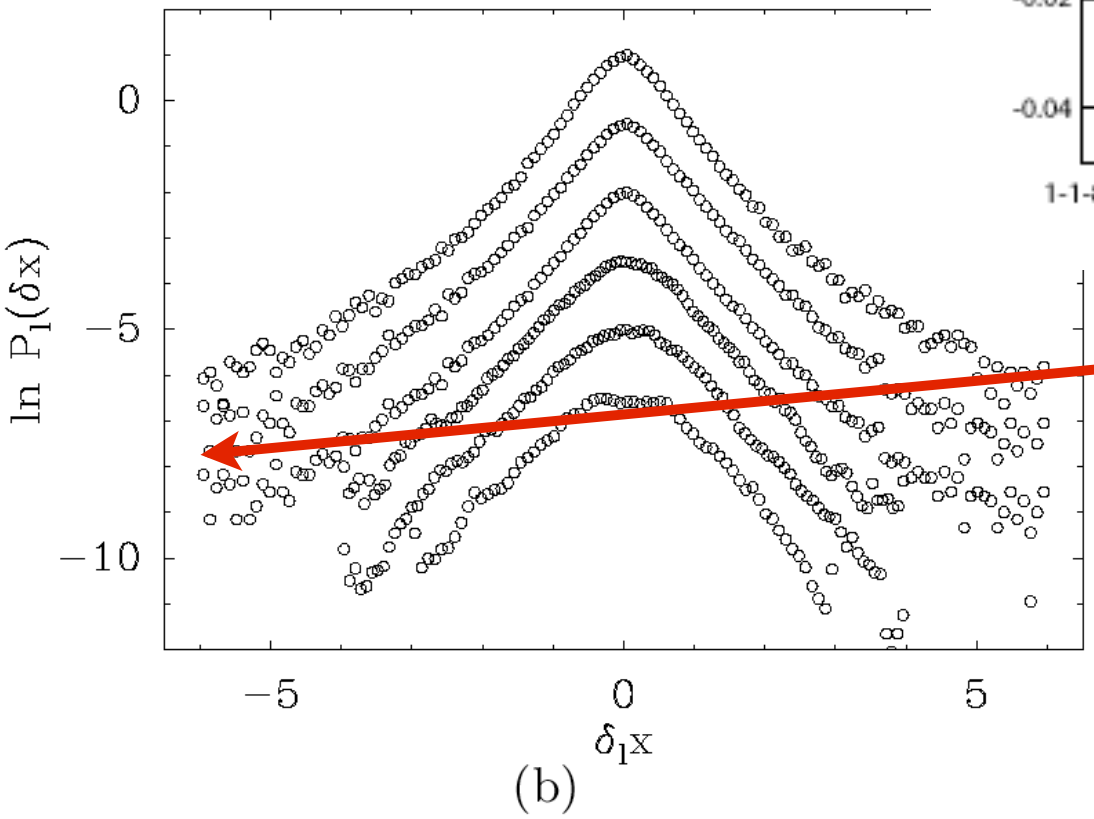
Brain medicine: Epileptic seizures

Geophysics: Characteristic earthquakes? Great avalanches? Floods? Mountain collapses? Meteological events? and so on

Financial crashes as "Black swans"?

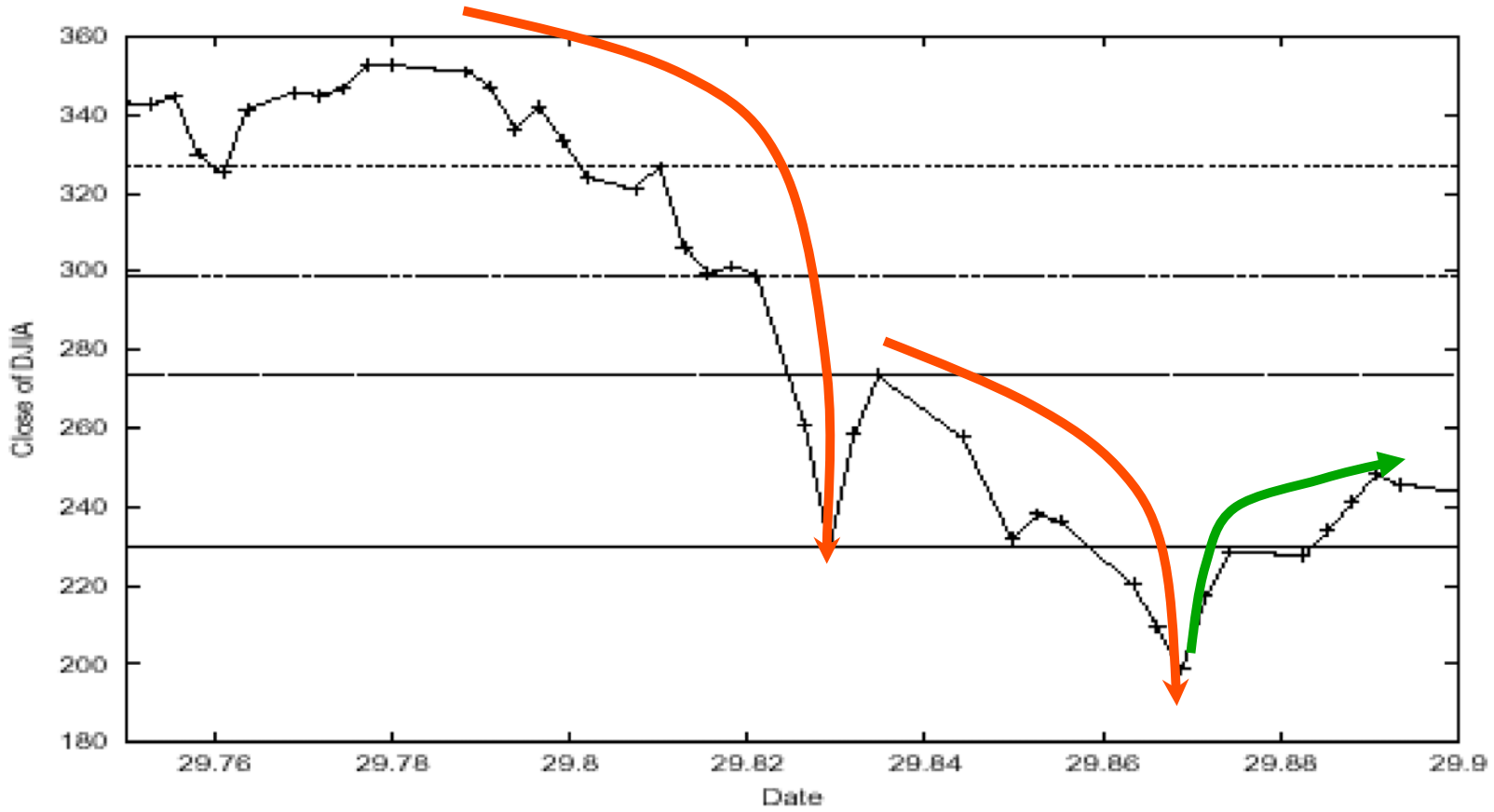
Traditional emphasis on
Daily returns do not reveal
any anomalous events



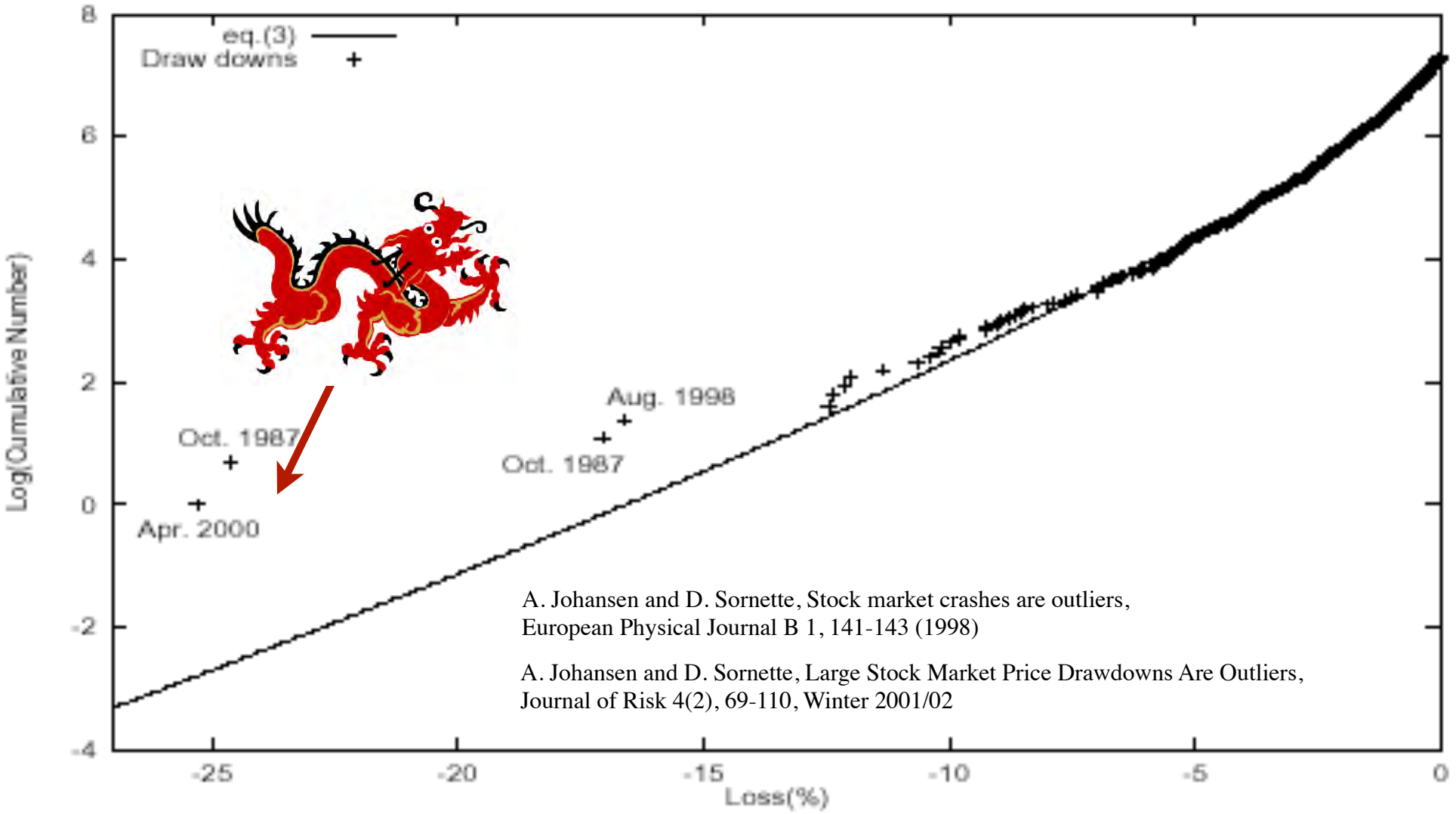


"Black swans"

Better risk measure: drawdowns



"Dragons" of financial risks



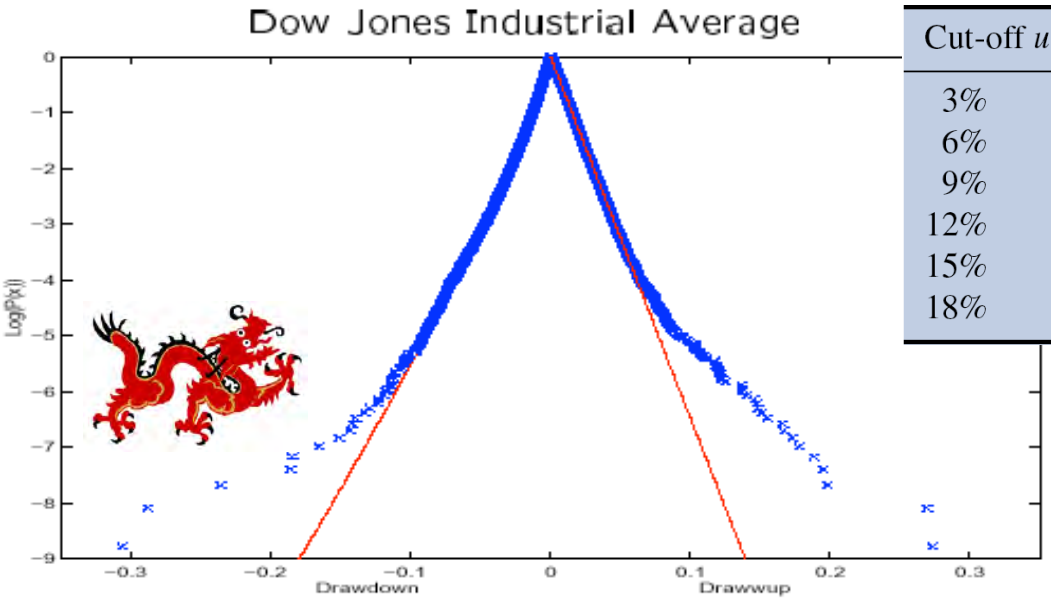
A. Johansen and D. Sornette, Stock market crashes are outliers, European Physical Journal B 1, 141-143 (1998)

A. Johansen and D. Sornette, Large Stock Market Price Drawdowns Are Outliers, Journal of Risk 4(2), 69-110, Winter 2001/02

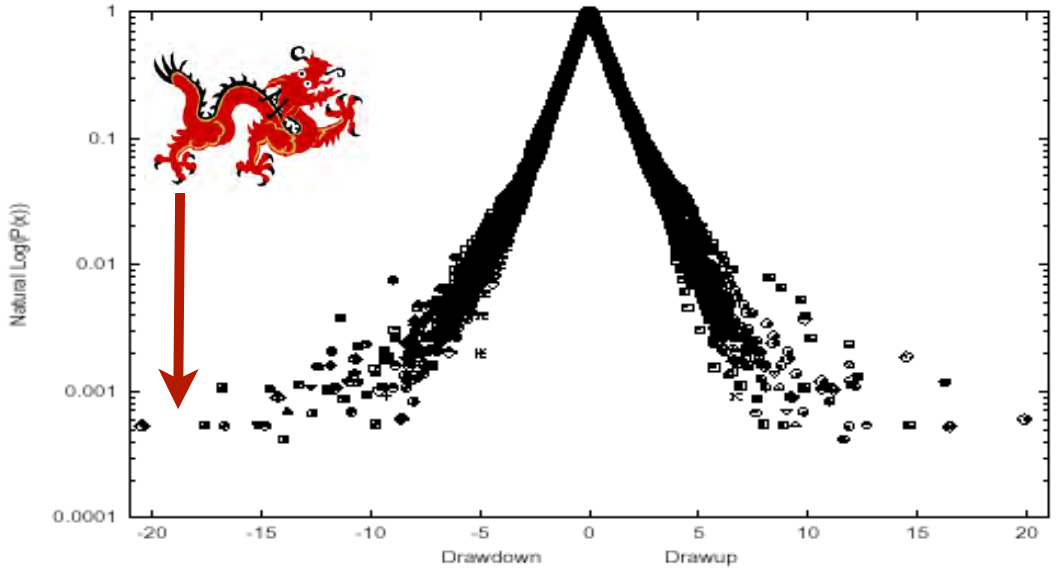
$$N(DD) = A \exp\left(-\left(|DD|/\chi\right)^{z}\right).$$

"Dragons" of financial risks

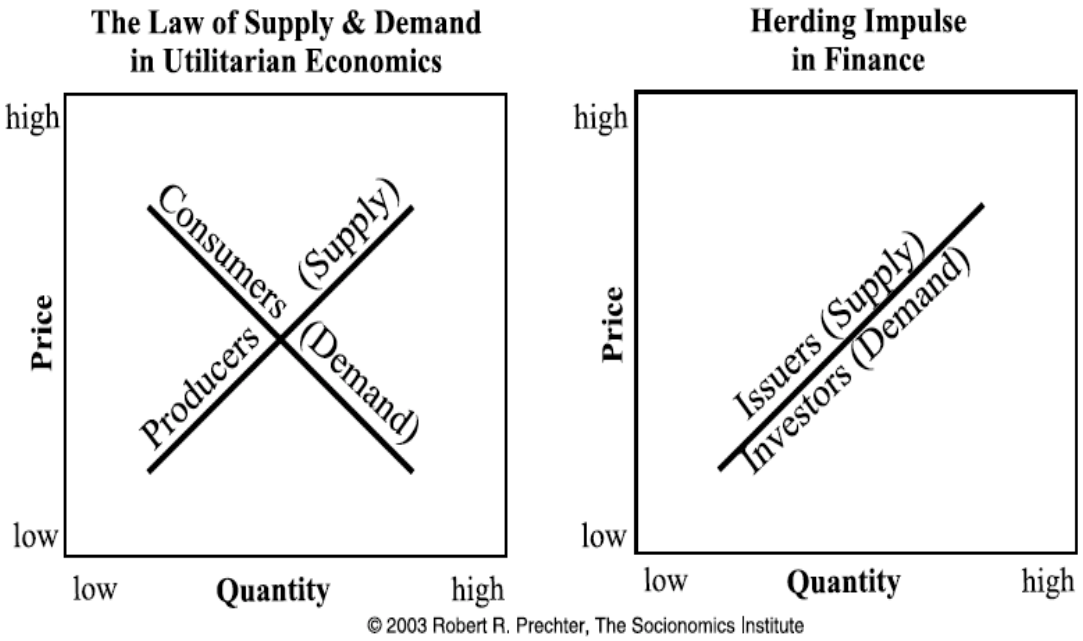
(require special mechanism and may be more predictable)



Cut-off u	Quantile	z	$\ln(L_0)$	$\ln(L_1)$	T	Proba
3%	87%	0.916, 0.940	4890.36	4891.16	1.6	20.5%
6%	97%	0.875, 0.915	4944.36	4947.06	5.4	2.0%
9%	99.0%	0.869, 0.918	4900.75	4903.66	5.8	1.6%
12%	99.7%	0.851, 0.904	4872.47	4877.46	10.0	0.16%
15%	99.7%	0.843, 0.898	4854.97	4860.77	11.6	0.07%
18%	99.9%	0.836, 0.890	4845.16	4851.94	13.6	0.02%



Positive feedbacks

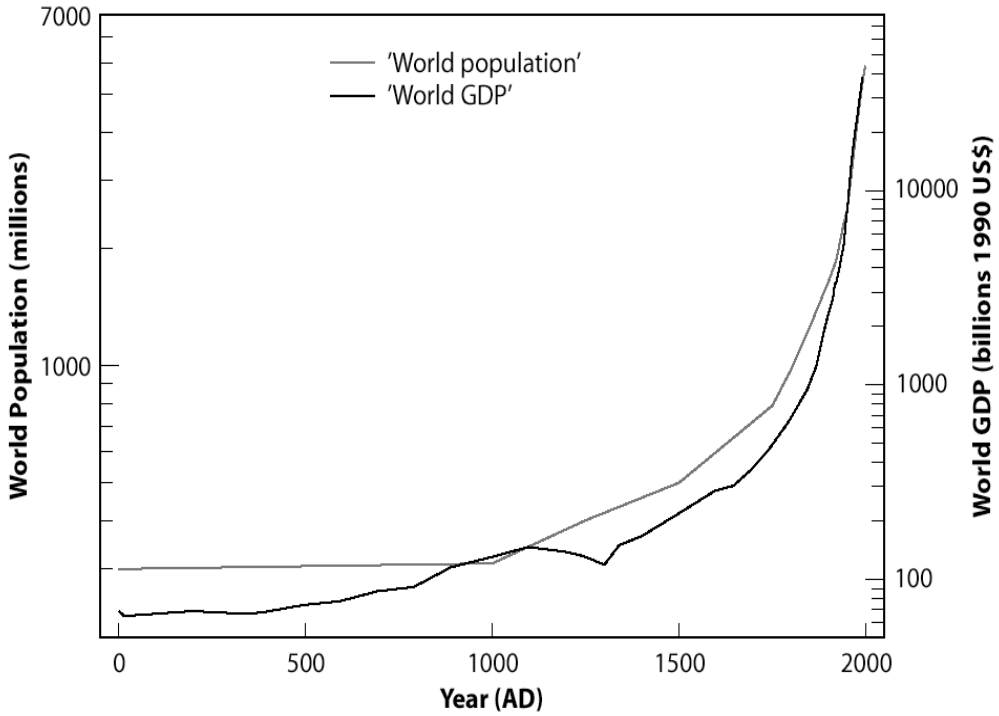


-bubble phase
-crash phase

$$\frac{dp}{dt} = cp^d$$

$$p(t) = \left(\frac{c}{m}\right)^{-m} (t_c - t)^{-m}$$

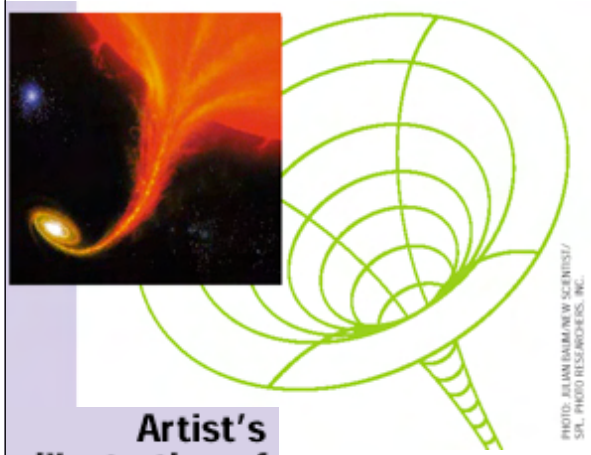
$$m = 1/(d-1) > 0 \text{ and } t_c = t_0 + mp_0^{1-d}/c.$$



Bubble preparing a crisis:
Faster than exponential
transient unsustainable
growth of price

Finite-time Singularity

as a result of positive feedbacks



Artist's illustration of matter from a red giant star being pulled toward a black hole.

- Planet formation in solar system by run-away accretion of planetesimals
- PDE's: Euler equations of inviscid fluids and relationship with turbulence
- PDE's of General Relativity coupled to a mass field leading to the formation of black holes
- Zakharov-equation of beam-driven Langmuir turbulence in plasma
- rupture and material failure
- Earthquakes (ex: slip-velocity Ruina-Dieterich friction law and accelerating creep)
- Models of micro-organisms chemotaxis, aggregating to form fruiting bodies
- Surface instability spikes (Mullins-Sekerka), jets from a singular surface, fluid drop snap-off
- Euler's disk (rotating coin)
- Stock market crashes...

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Paris as a king-dragon

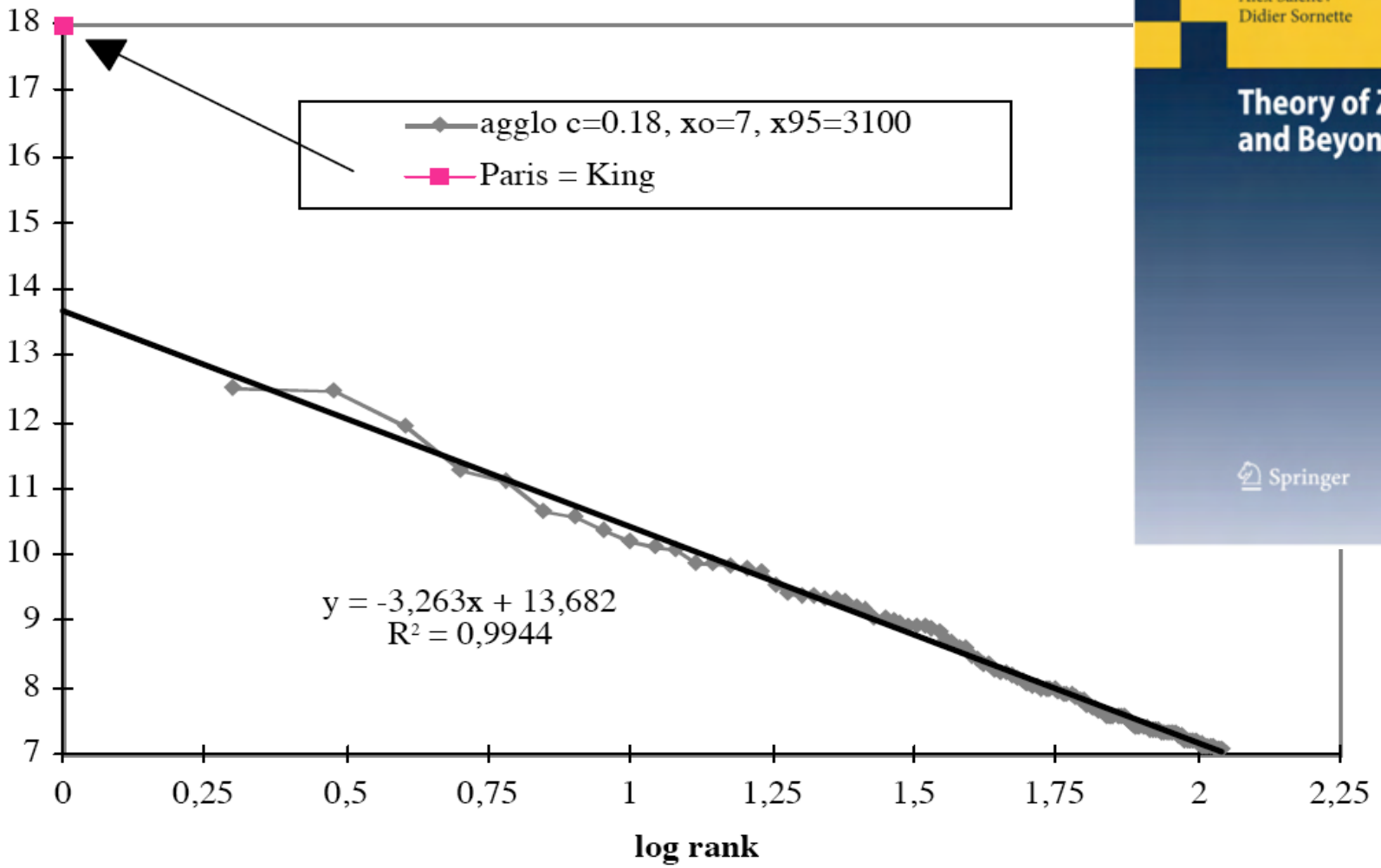
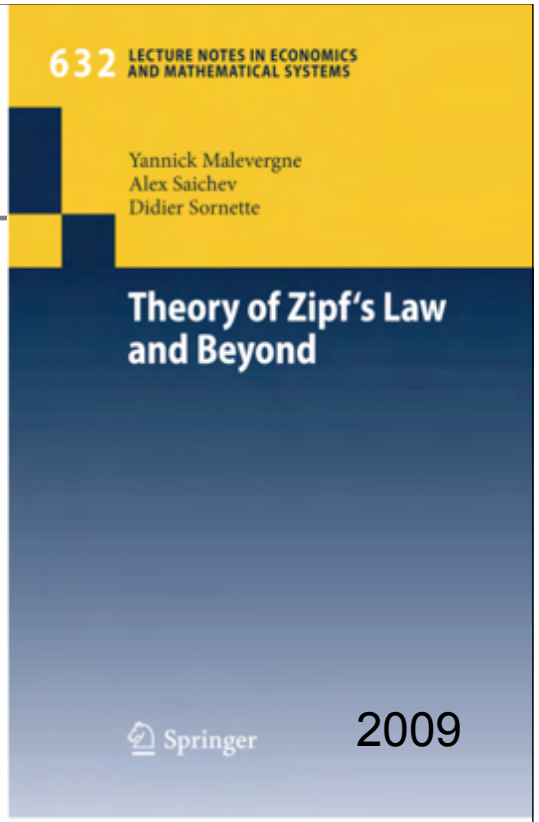


Fig. 7. French agglomerations: stretched exponential and "King effect".



Jean Laherrere and Didier Sornette, Stretched exponential distributions in Nature and Economy: ``Fat tails" with characteristic scales, European Physical Journal B 2, 525-539 (1998)

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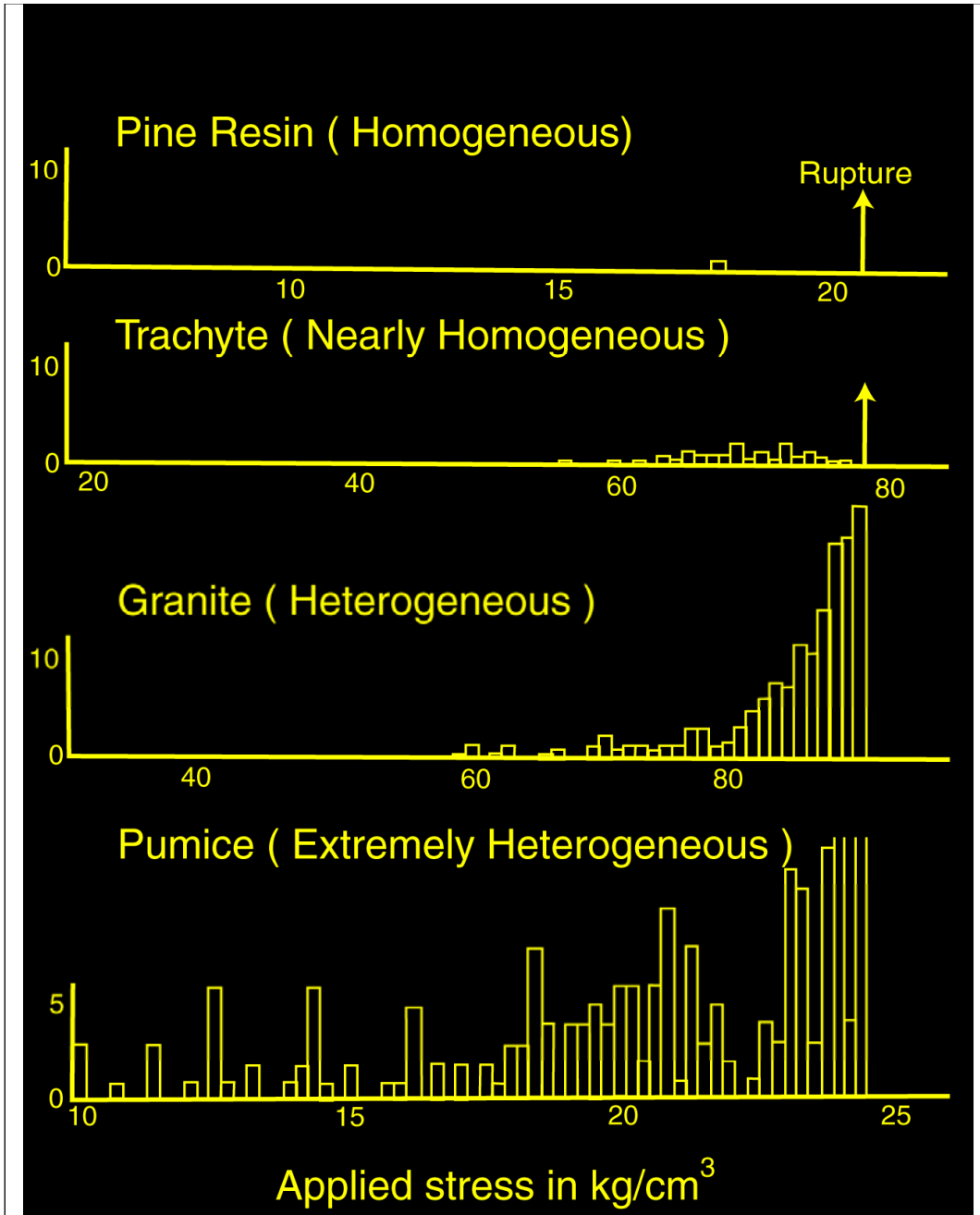
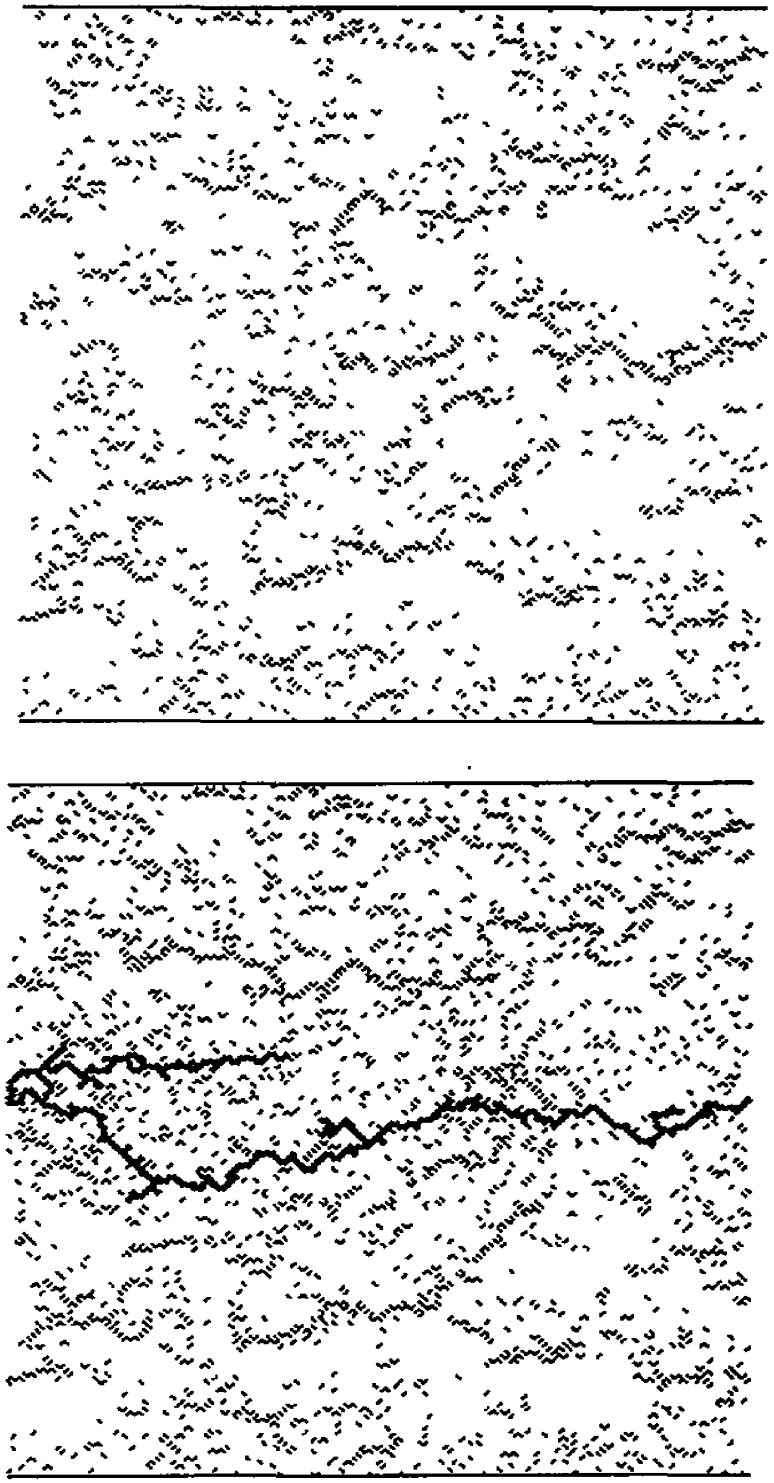
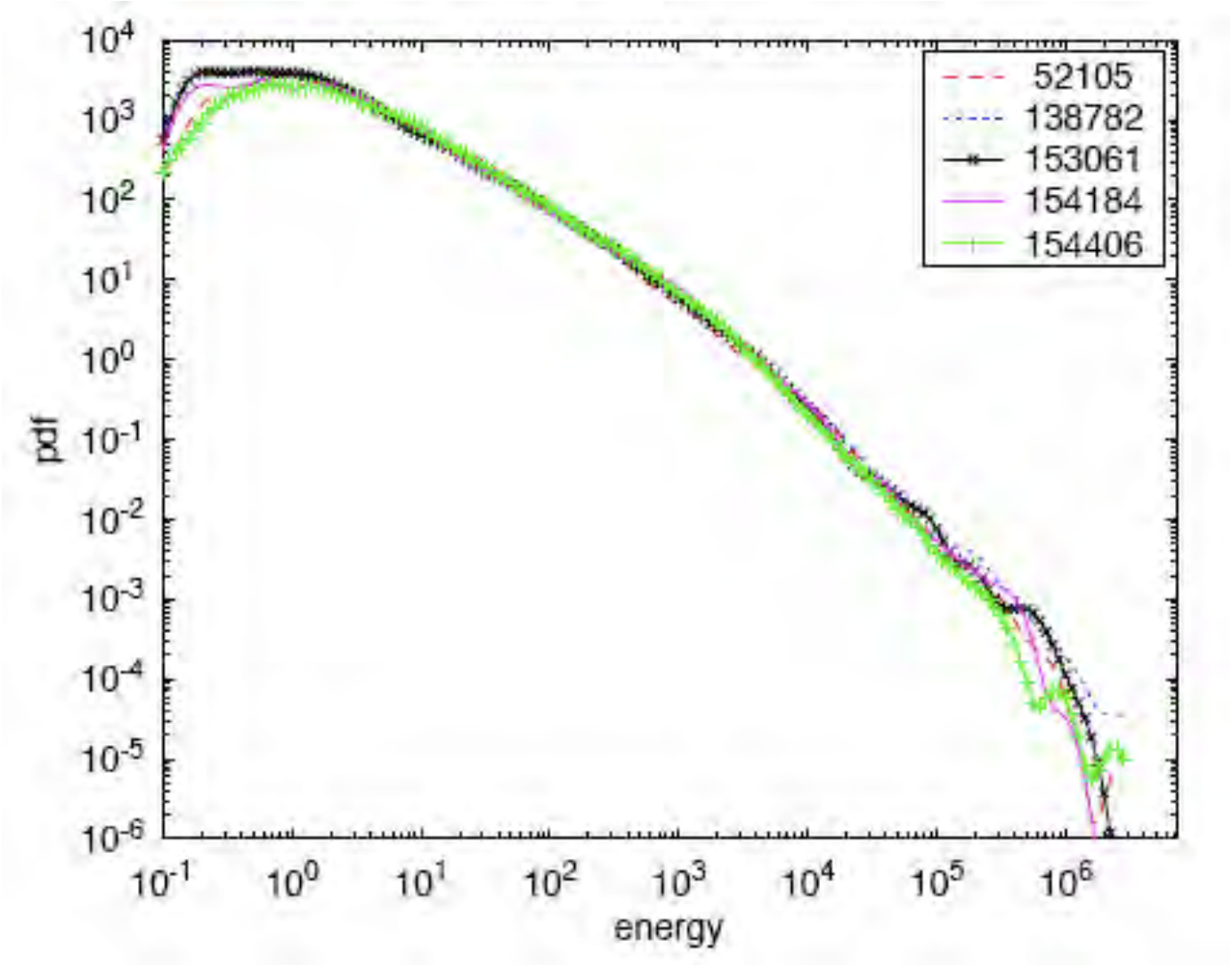


Fig. 4. Frequency of elastic shocks under increasing stresses in materials with different heterogeneity. From Mogi [1962]





H. Nechad, A. Helmstetter, R. El Guerjouma and D. Sornette, Andrade and Critical Time-to-Failure Laws in Fiber-Matrix Composites: Experiments and Model, Journal of Mechanics and Physics of Solids (JMPS) 53, 1099-1127 (2005)

• • •

Energy distribution for the [+-62] specimen #4 at different times, for 5 time windows with 3400 events each. The average time (in seconds) of events in each window is given in the caption.

time-to-failure analysis

S.G. Sammis and D. Sornette, Positive Feedback, Memory and the Predictability of Earthquakes, Proceedings of the National Academy of Sciences USA, V99 SUPP1:2501-2508 (2002 FEB 19)

Beyond power laws: 7 examples of "Dragons"

Financial economics: Outliers and dragons in the distribution of financial drawdowns.

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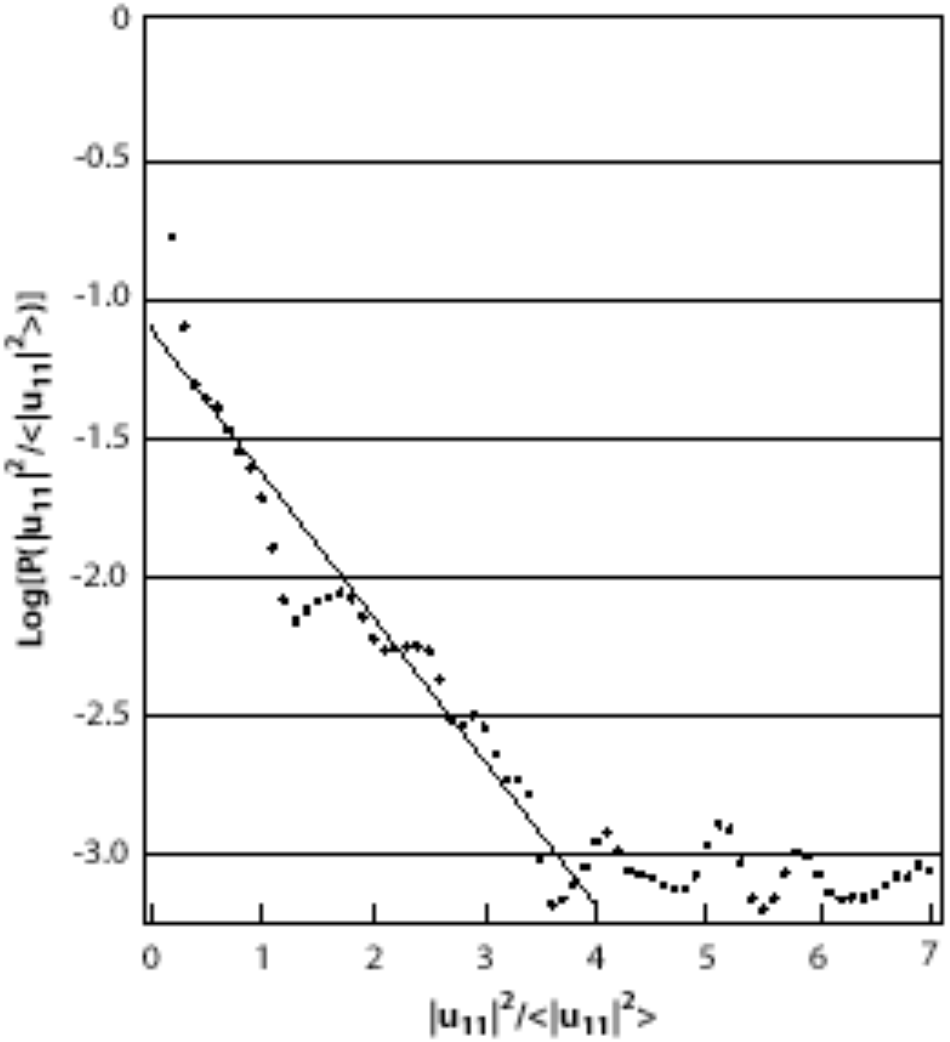
Mathematical Geophysics Conference

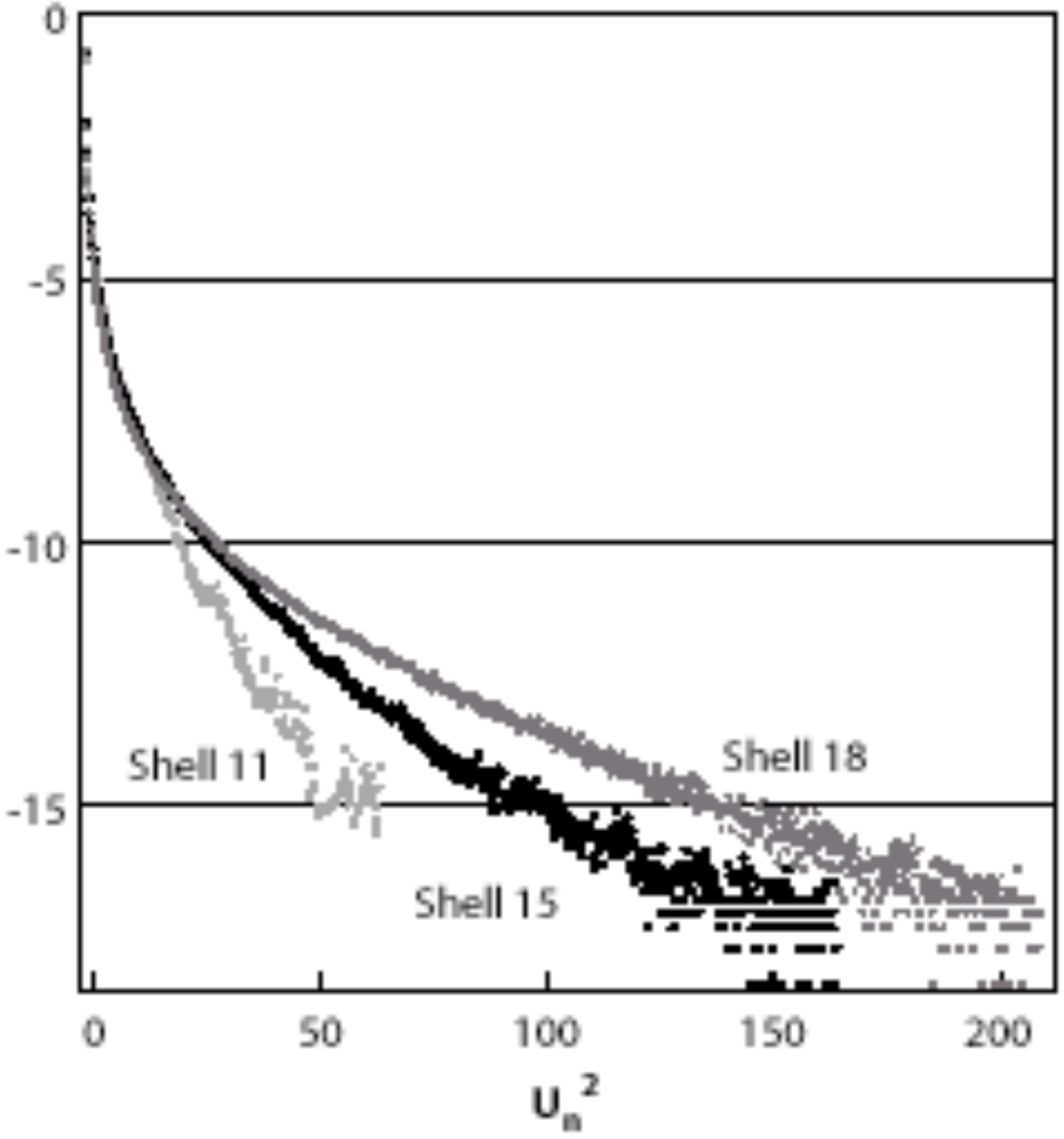
Extreme Earth Events

Villefranche-sur-Mer, 18-23 June 2000



L'vov, V.S., Pomyalov, A. and Procaccia, I. (2001) Outliers, Extreme Events and Multiscaling, Physical Review E 6305 (5), 6118, U158-U166.

FIG. 3.2. Apparent probability distribution function of the square of the fluid velocity, normalized to its time average, in the eleventh shell of the toy model of hydrodynamic turbulence discussed in the text. The vertical axis is in logarithmic scale such that the straight line, which helps the eye, qualifies as an apparent exponential distribution. Note the appearance of extremely sparse and large bursts of velocities at the extreme right above the extrapolation of the straight line. Reproduced from [252].



Pdf of the square of the Velocity as in the previous figure but for a much longer time series, so that the tail of the distributions for large Fluctuations is much better constrained. The hypothesis that there are no outliers is tested here by collapsing the distributions for the three shown layers. While this is a success for small fluctuations, the tails of the distributions for large events are very different, indicating that extreme fluctuations belong to a different class of their own and hence are outliers.

L'vov, V.S., Pomyalov, A. and Procaccia, I. (2001) Outliers, Extreme Events and Multiscaling, Physical Review E 6305 (5), 6118, U158-U166.

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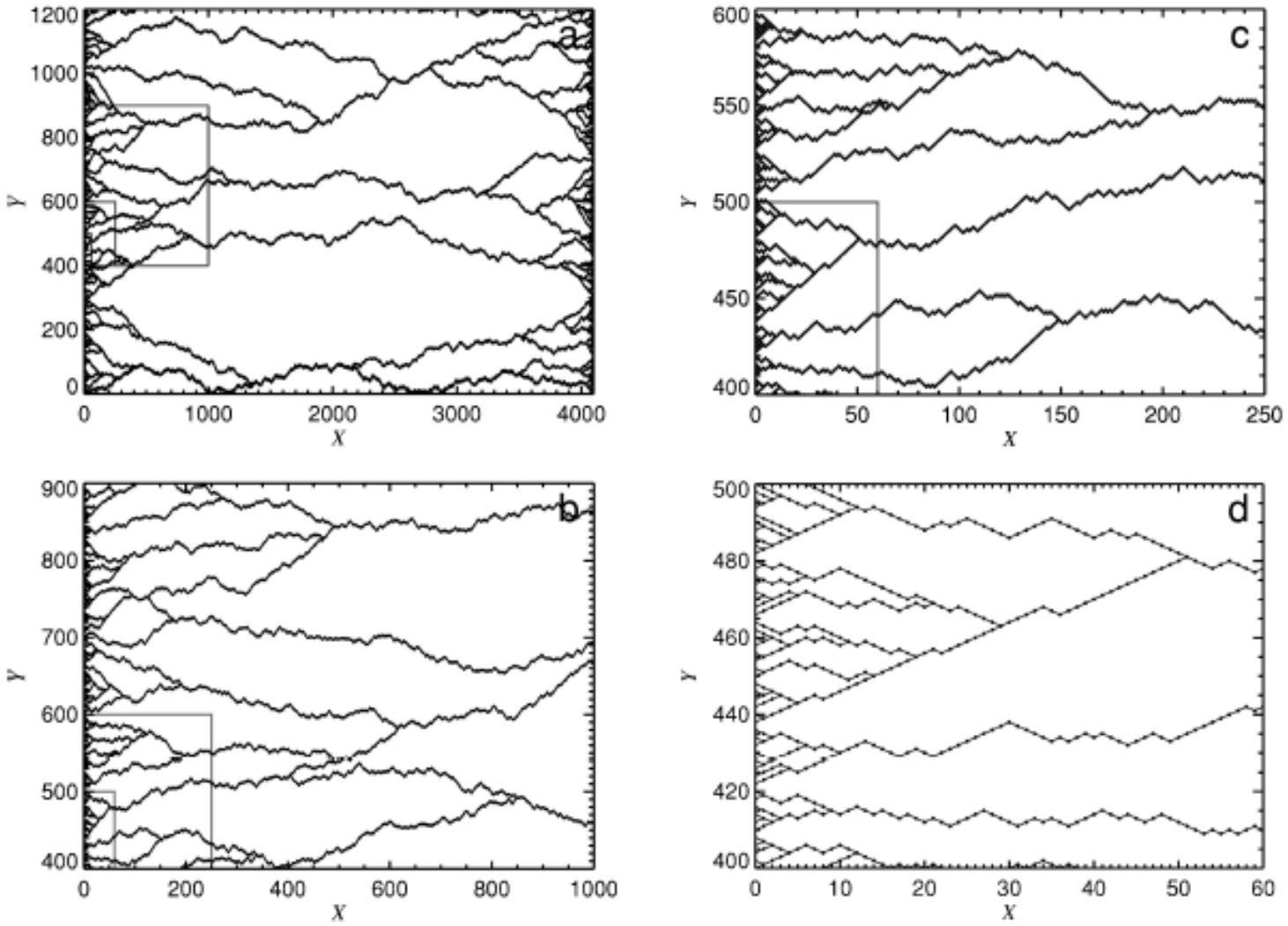
Metastable states in random media

Self-organized critical random directed polymers



P. Jogi and D. Sornette, Self-organized critical random directed polymers, Phys. Rev. E 57, 6931-6943 (1998)

FIG. 1. Typical set of optimal configurations for a RDP of length $W=4096$ and for $0 \leqslant y \leqslant 1200$: (a) global system [gray framed boxes outline regions of succeeding plots such that the horizontal and vertical extensions of these boxes follow Eqs. (10) and (8) with $\alpha \approx 0.9$], (b) magnification of the largest box in (a), (c) magnification of the largest box in (b) and (d) magnification of the box in (c). Note, that at each grid point of the lattice we assign an independent random number drawn from an exponential distribution with unit mean and variance.

Definition of “avalanches”

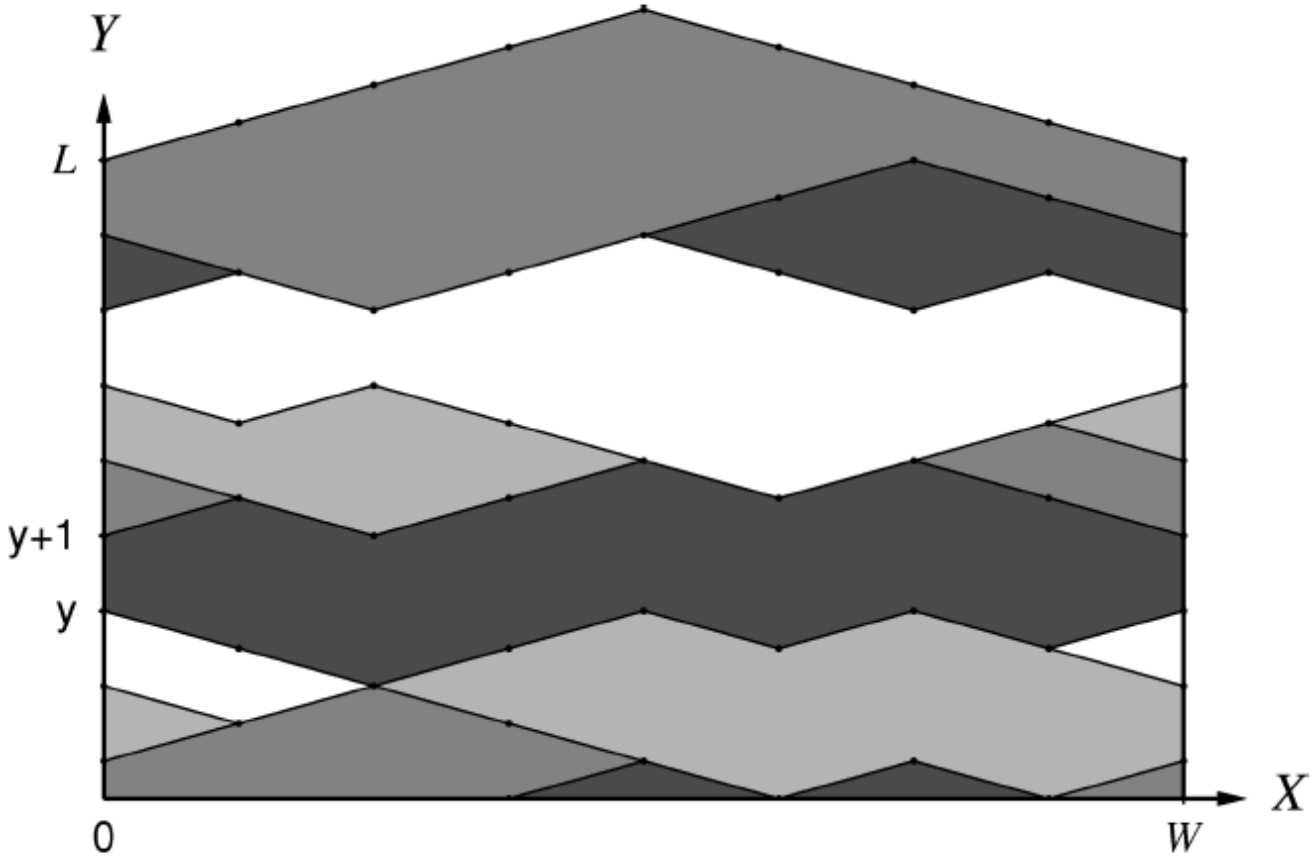


FIG. 2. Schematic representation of optimal RDPs fixed at their two end points. An avalanche is defined by the area S spanned by the transition from the optimal configuration at y to $y+1$, i.e., S is the area interior to the perimeter formed by the union of the two optimal RDP configurations at y and $y+1$ and the two vertical segments $((0,y);(0,y+1))$ and $((W,y);(W,y+1))$. The successive avalanches are represented in different gray scales.

$$P(S)dS \propto \frac{W^{2/3}}{S^{1+\mu}} dS,$$

$$\mu = 2/5.$$

+ characteristic avalanche scale ~ $W^{5/3}$

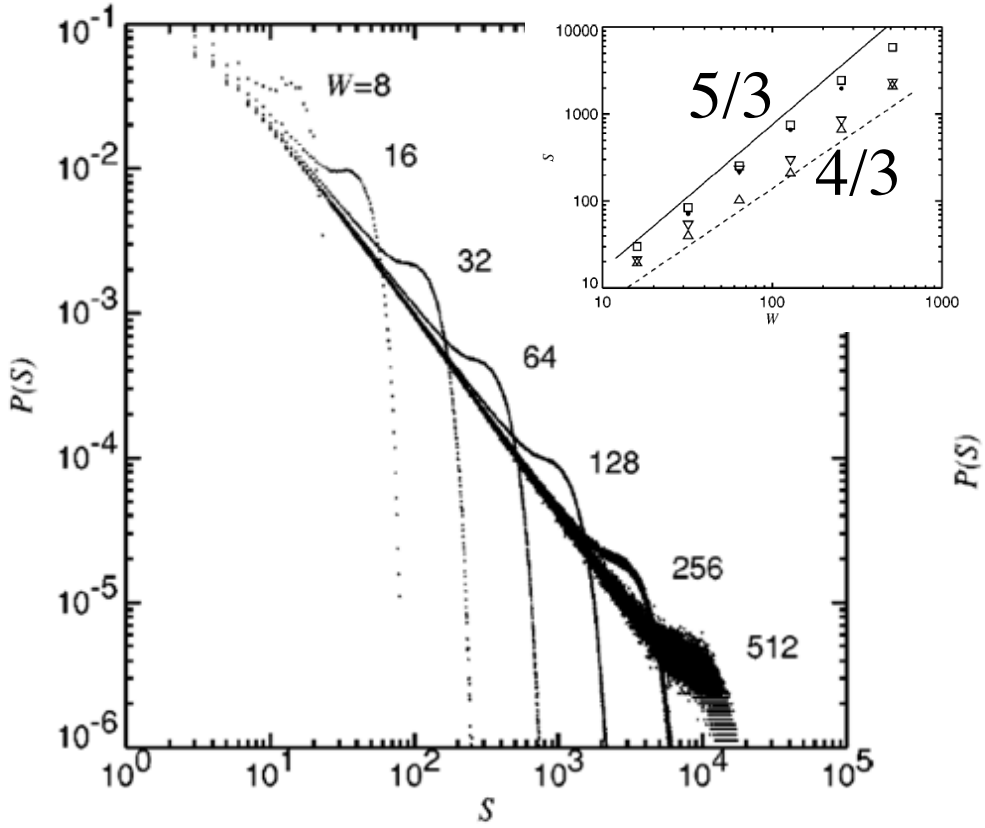


FIG. 3. Distribution $P(S)$ of RDP avalanche sizes obtained numerically for system widths from $W=8$ to 512 on a log-log plot. Here the system lengths L are 2×10^7 (for $W=8$), 3×10^6($W=16$), 2×10^7($W=32$), 10^8($W=64$), 2×10^8($W=128$),5×10^7($W=256$), and 9×10^6($W=512$).

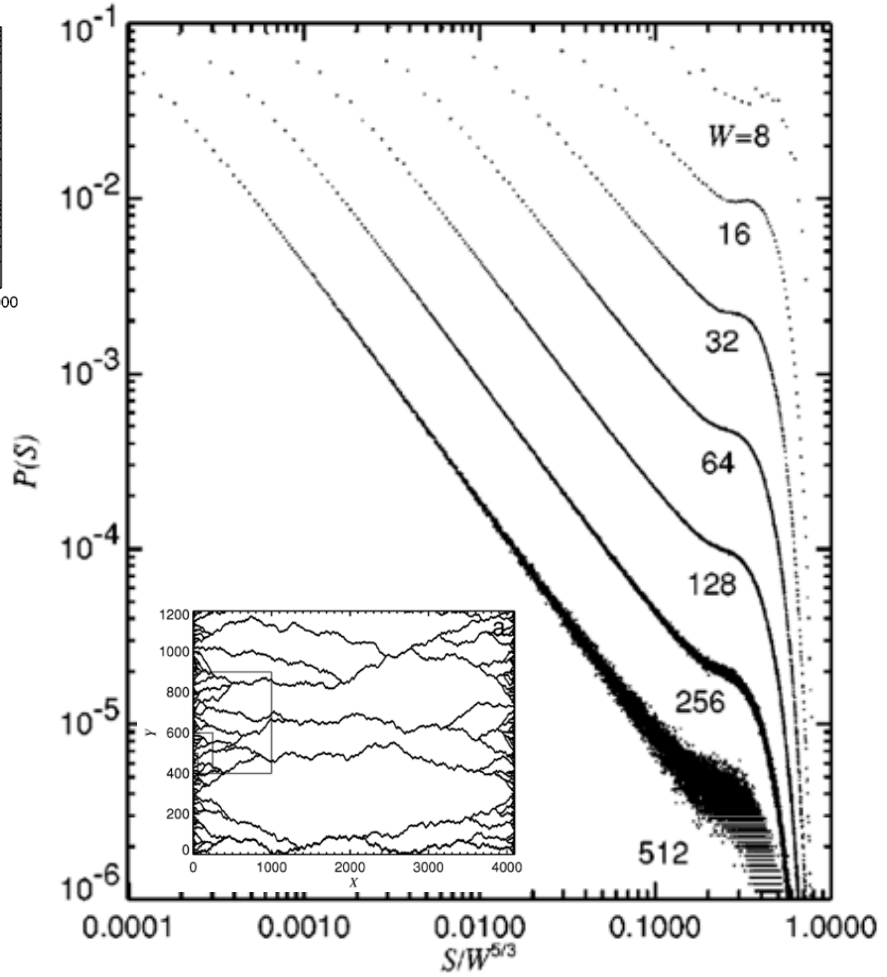


FIG. 4. $P(S)$ as a function of the rescaled variable $S/W^{5/3}$ for $W=8$–512 on a log-log plot.

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Brain medicine: Epileptic seizures

Geophysics: Characteristic earthquakes? Great avalanches? Floods? Mountain collapses? Meteological events? and so on

1. Geosciences of the solid envelop

1.1. Earthquake magnitude.
1.2. Volcanic eruptions.
1.3. Landslides.
1.4. Floods. No protagonist found yet.

Special Issue SPRINGER
G. Ouillon and D. Sornette
Guest Editors (2011)

2. Meteorological and Climate sciences

2.1. Rains, hurricanes, storms.
2.2. Snow avalanches.

3. Material Sciences and Mechanical Engineering

3.1. Acoustic emissions.
3.2. Hydrodynamic turbulence.

4. Economics : financial drawdowns, distribution of wealth

5. Social sciences: distribution of firm sizes, of city sizes, of social groups...

6. Social sciences : wars, strikes, revolutions, city sizes

7. Medicine: epileptic seizures, epidemics

8. Environmental sciences : extinctions of species, forest fires

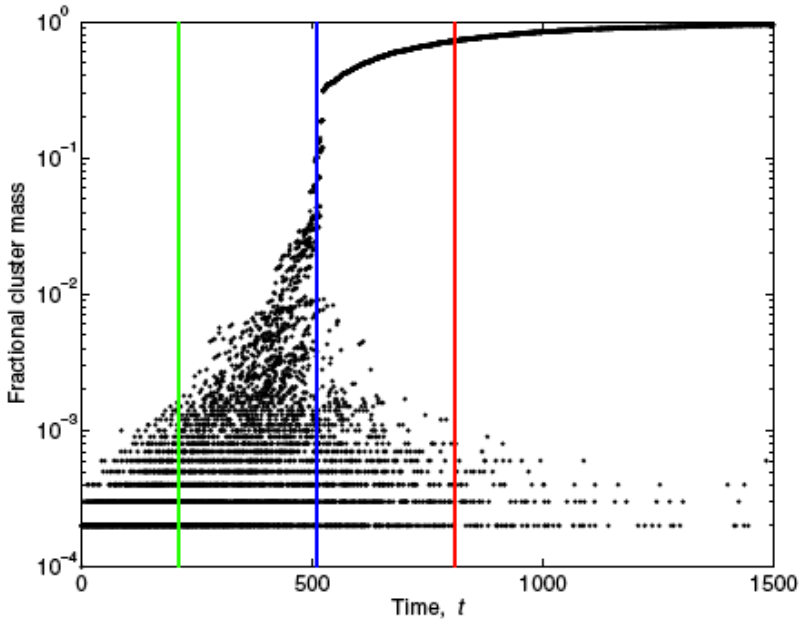
8.1. Evolution and extinction of species.
8.2. Forest fires.

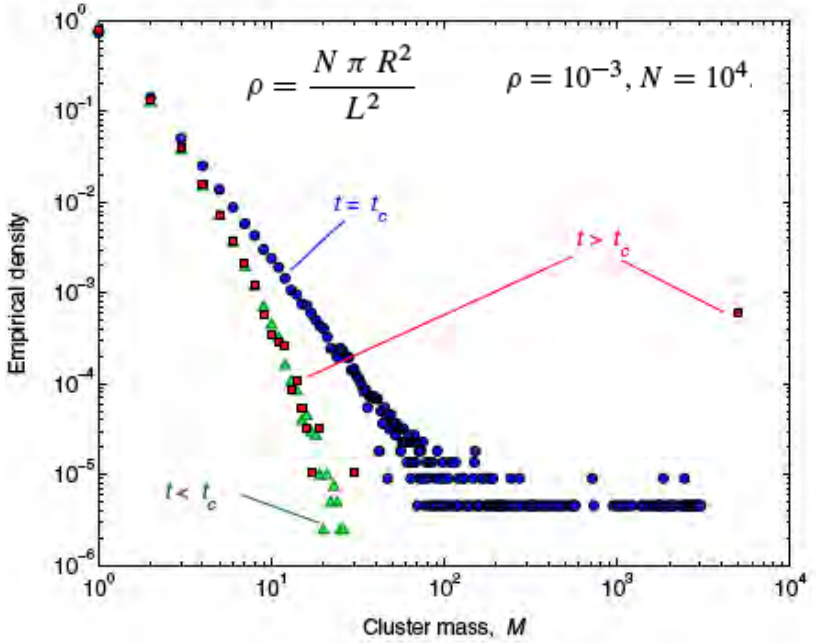
Mechanisms for Dragon-kings

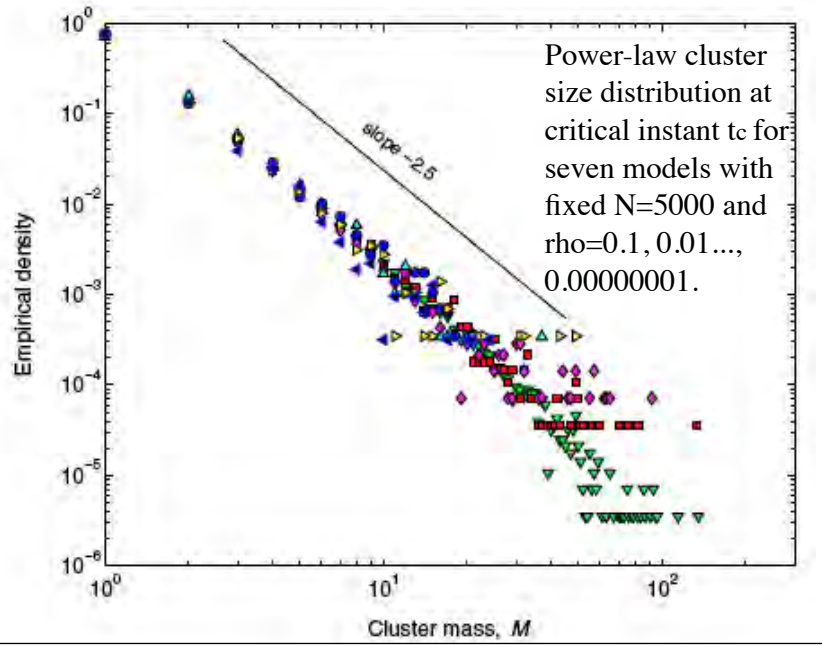
- Generalized correlated percolation
- A kind of condensation (a la Bose-Einstein)
- Partial global synchronization

Dynamic clustering in N balls in a billiard

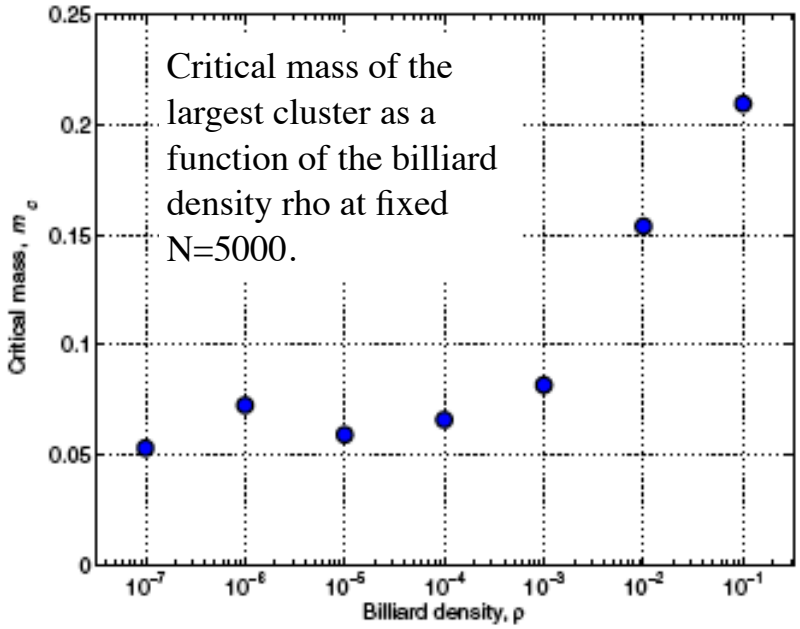
Two balls are D-*neighbors* at epoch t if they collided during the time interval [t-D, t].
Any connected component of this neighbor relation is called a D-cluster at epoch t .







Power-law cluster size distribution at critical instant tc for seven models with fixed N=5000 and rho=0.1, 0.01..., 0.00000001.



Critical mass of the largest cluster as a function of the billiard density rho at fixed N=5000.

Gabrielov, A., V. Keilis-Borok, Y. Sinai, and I. Zaliapin (2008) Statistical properties of the cluster dynamics of the systems of statistical mechanics. ESI Lecture Notes in Mathematics and Physics: Boltzmann's Legacy, European Mathematical Society, G. Gallavotti, W. Reiter and J. Yngvason (Eds.), 203-216.

Landau-Ginzburg Theory of Self-Organized Criticality
and of Dragon-kings!

Dynamics of an order parameter (OP) and of the corresponding *control* parameter (CP): within the sandpile picture, $\frac{\partial h}{\partial x}$ is the slope of the sandpile, h being the local height, and S is the state variable distinguishing between static grains ($S = 0$) and rolling grains ($S \neq 0$).

L. Gil and D. Sornette "Landau-Ginzburg theory of self-organized criticality", Phys. Rev.Lett. 76, 3991-3994 (1996)

Normal form of sub-critical bifurcation

$$\frac{\partial S}{\partial t} = \chi \left\{ \mu S + 2\beta S^3 - S^5 \right\} \qquad (1)$$

where

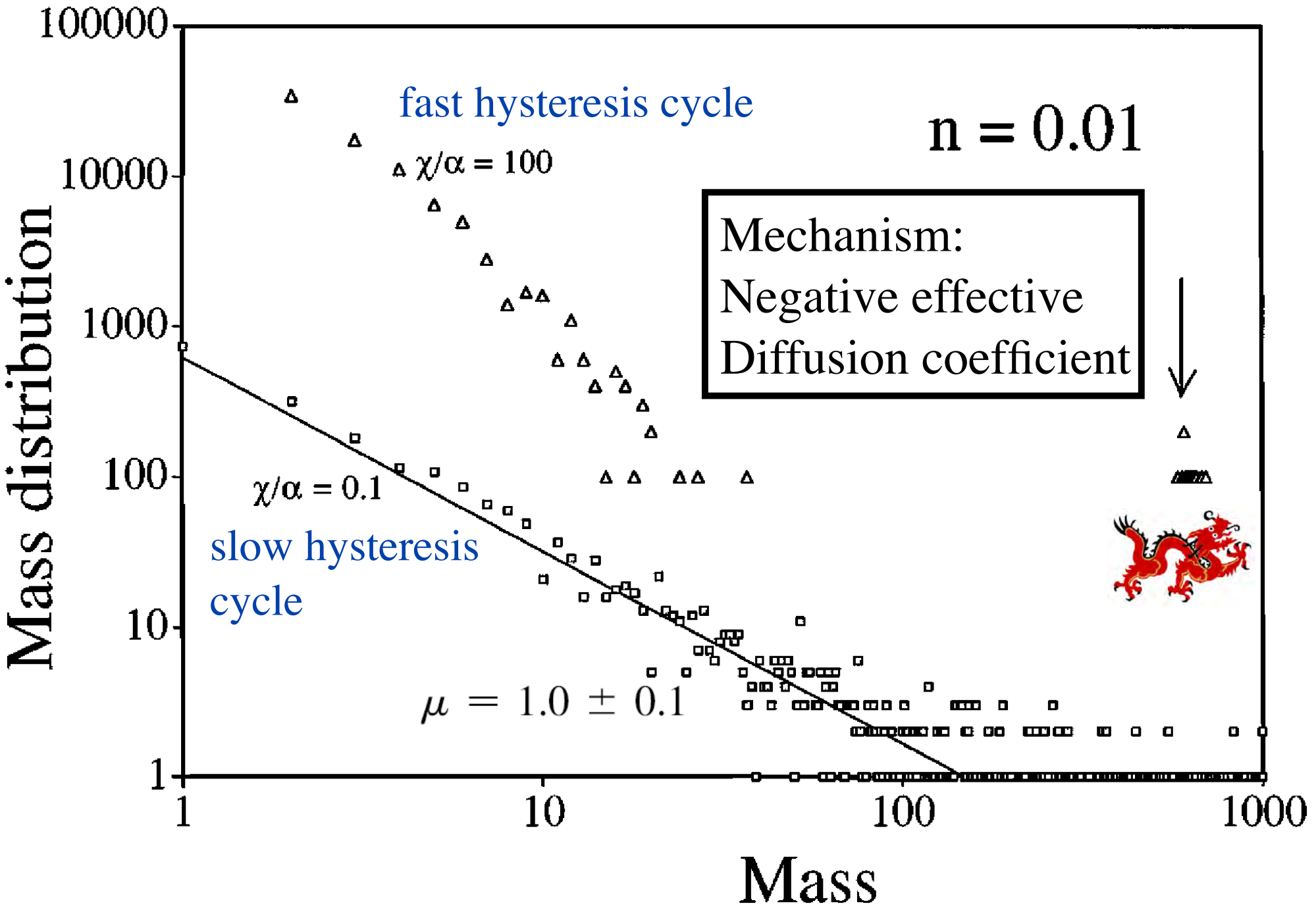
$$\mu = \left[\left(\frac{\partial h}{\partial x} \right)^2 - \left(\frac{\partial h}{\partial x}|_c \right)^2 \right] \qquad (2)$$

and $\beta > 0$ (subcritical condition).

$$F\left(S, \frac{\partial h}{\partial x}\right) = -\alpha \frac{\partial h}{\partial x} S^2, \qquad \alpha > 0$$

Diffusion equation

$$\frac{\partial h}{\partial t} = -\frac{\partial F\left(S, \frac{\partial h}{\partial x}\right)}{\partial x} + \Phi \qquad (3)$$



System sizes range from $L/a = 64$ to 2048.

$$P(M)dM \simeq M^{-(1+\mu)}dM,$$

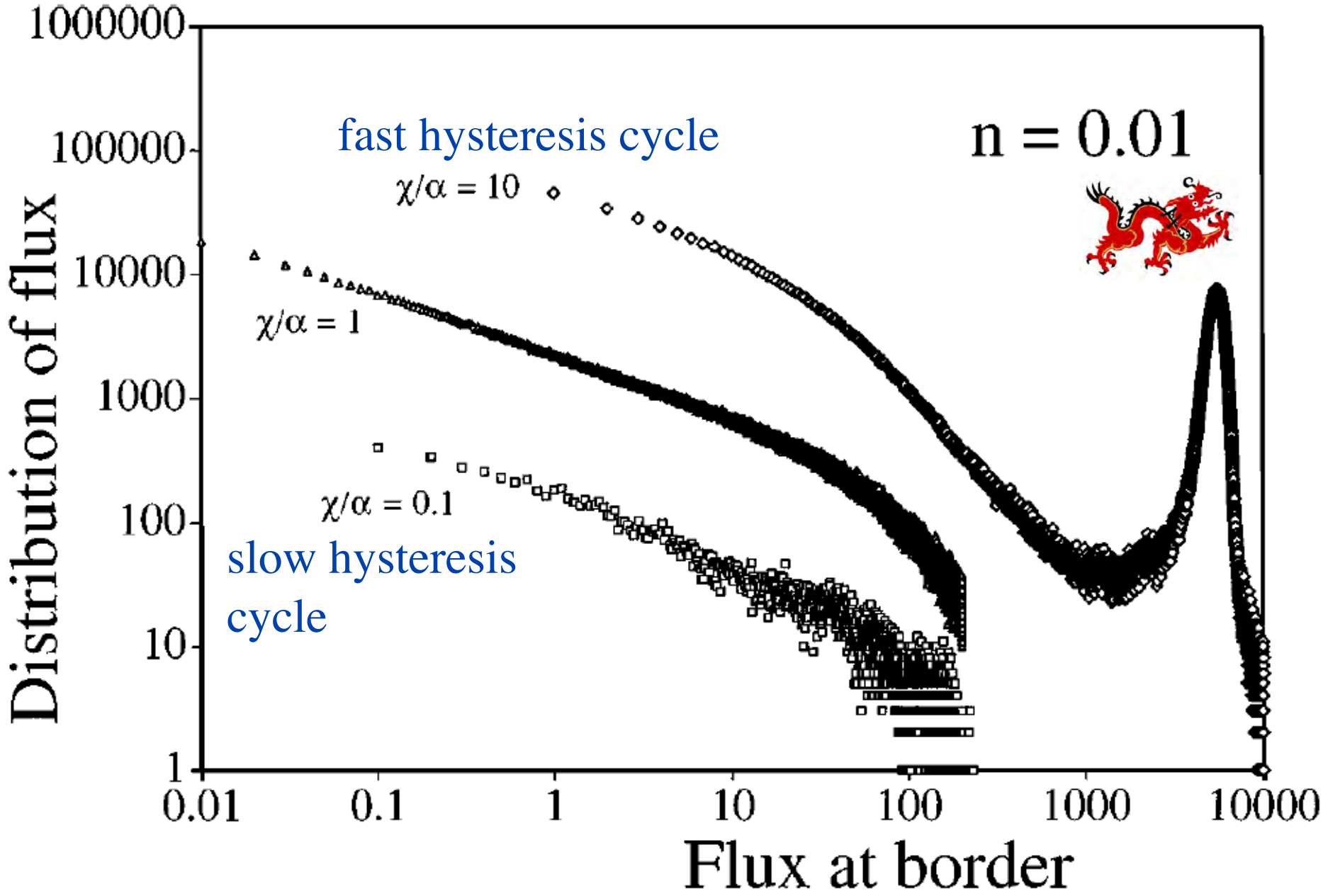
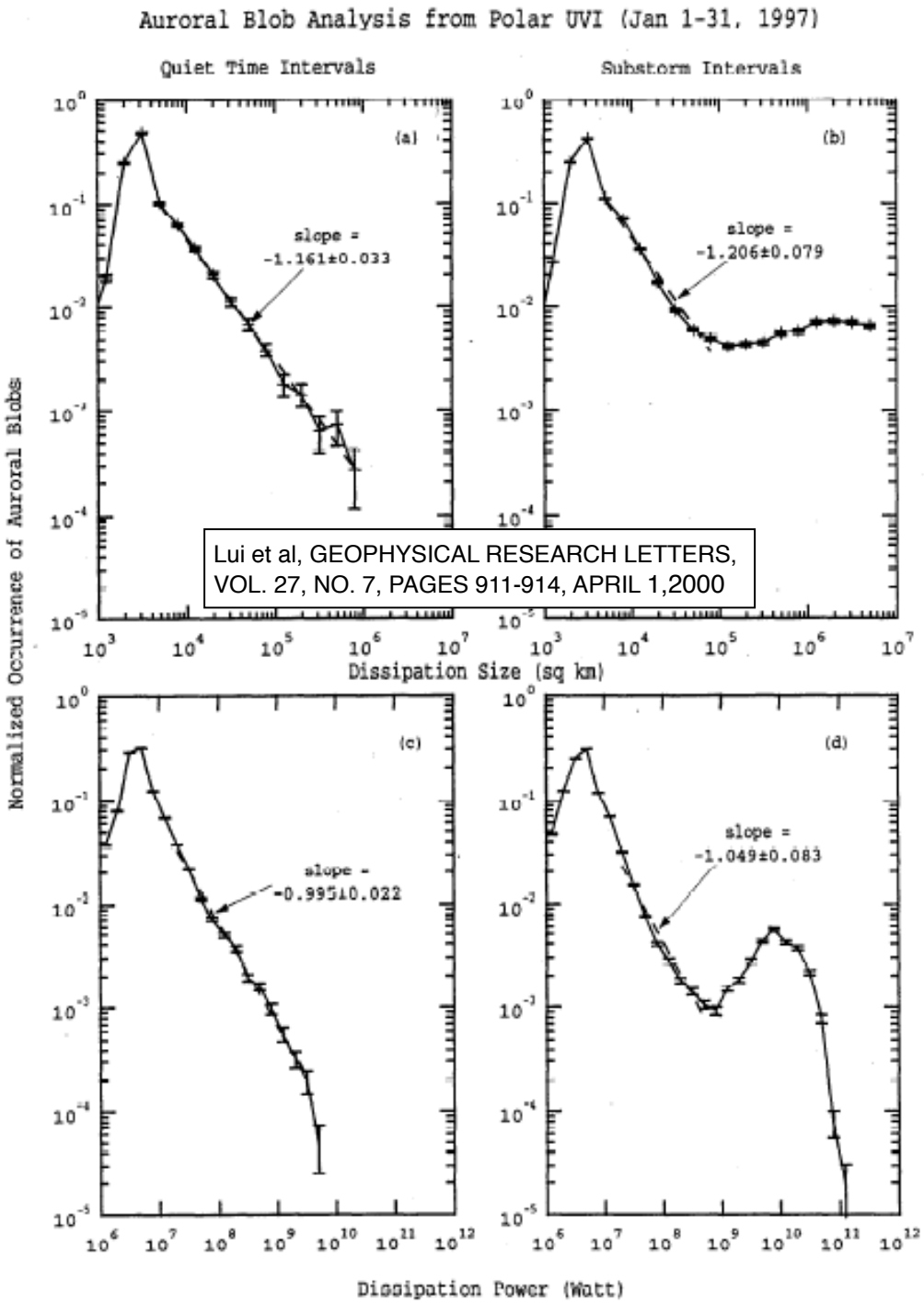


FIG. 3. Distribution $P(J)$ of flux amplitudes at the right border, in the same conditions as for Fig. 1.

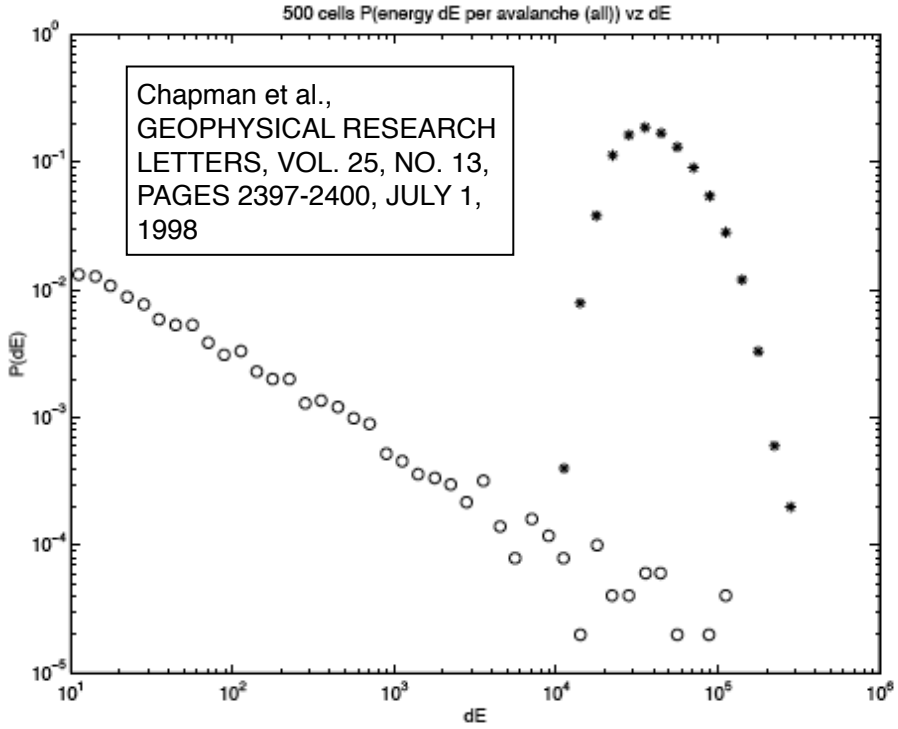
Global auroral energy deposition



Lui et al, GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 7, PAGES 911-914, APRIL 1,2000

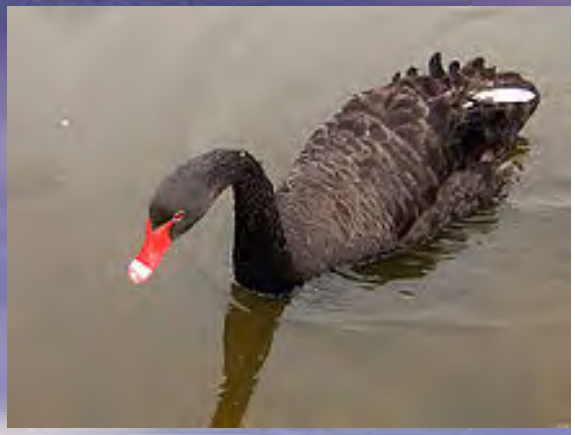
Probability distribution of size and power output of individual aurora region.
(a) size distribution during quiet times.
(b) size distribution during substorms.
(c) power distribution during quiet times.
(d) power distribution during substorms.

A simple avalanche model as an analogue for magnetospheric activity



Chapman et al., GEOPHYSICAL RESEARCH LETTERS, VOL. 25, NO. 13, PAGES 2397-2400, JULY 1, 1998

Crises are not black swans but "Dragon-kings"



Black Swan (*Cygnus atratus*)

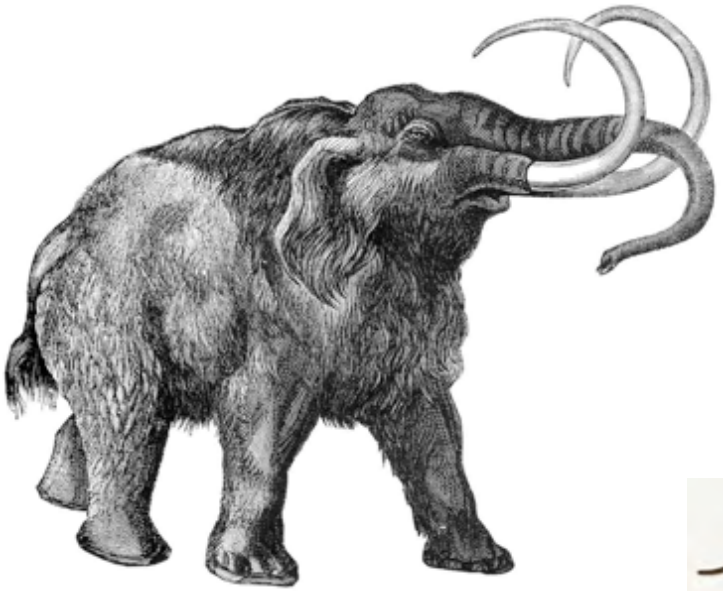
10% daily drop on Nasdaq : 1/1000 probability

1 in 1000 days => 1 day in 4 years

30% drop in three consecutive days?

(1/1000)*(1/1000)*(1/1000) = (1/1000’000’000)

=> one event in 4 millions years!



Mechanisms for positive feedbacks in the stock market

- Technical and rational mechanisms
  1. Option hedging
  2. Insurance portfolio strategies
  3. Trend following investment strategies
  4. Asymmetric information on hedging strategies

- Behavioral mechanisms:
  1. Breakdown of "psychological Galilean invariance"
  2. Imitation(many persons)
     a) It is rational to imitate
     b) It is the highest cognitive task to imitate
     c) We mostly learn by imitation
     d) The concept of "CONVENTION" (Orléan)
  3. "Social Proof" mechanism

Dragon-king story (for finance)

Dragon-king-outlier drawdowns

↓

Require new different mechanism

↓

Follow excesses ("bubbles")

↓

Bubbles are collective endogenous excesses
fueled by positive feedbacks

↓

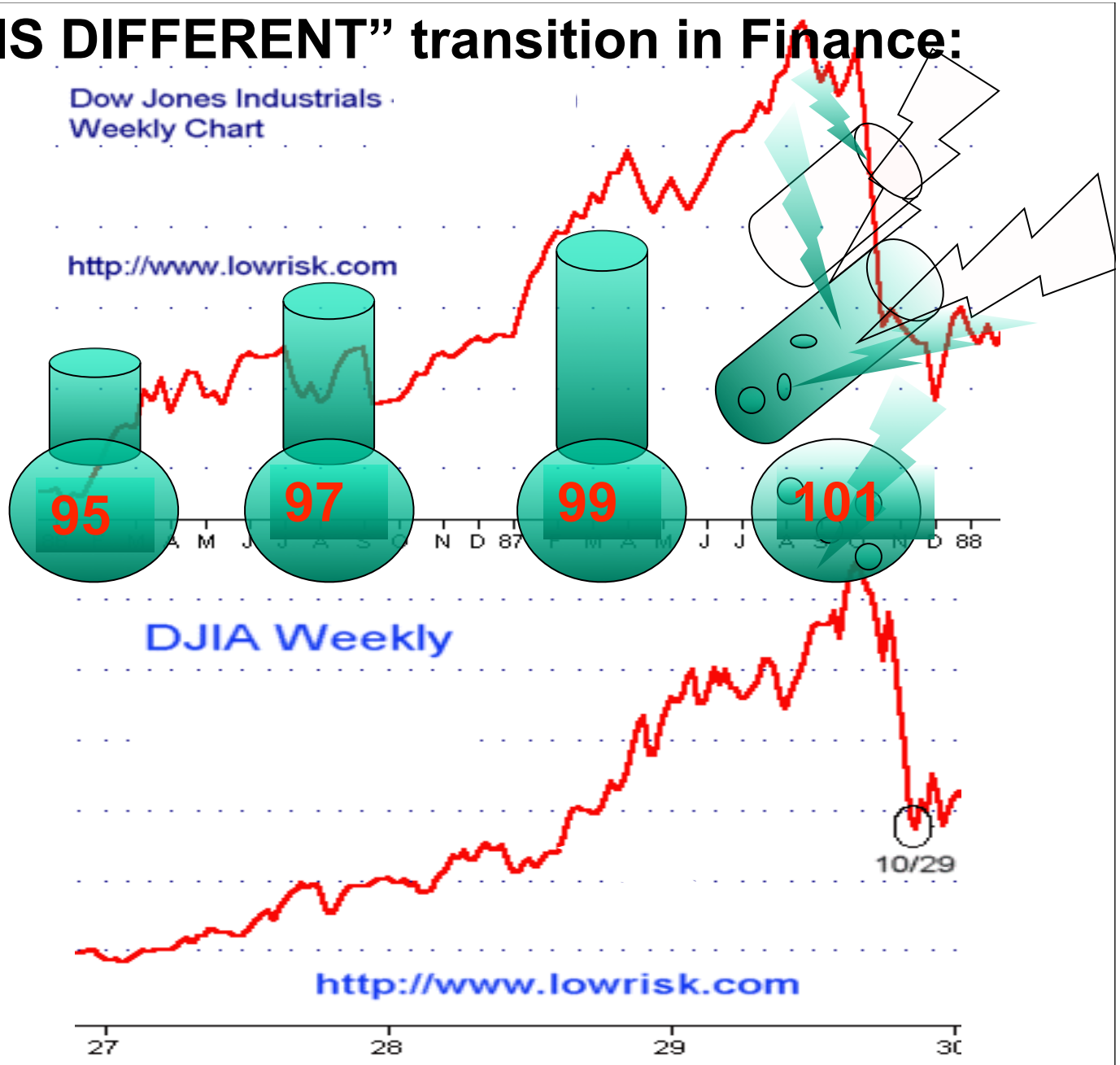
Most crises are "endogenous"

↓

Possible diagnostic and predictions
via "coarse-grained" metrics (forest versus trees)

Example of "MORE IS DIFFERENT" transition in Finance:

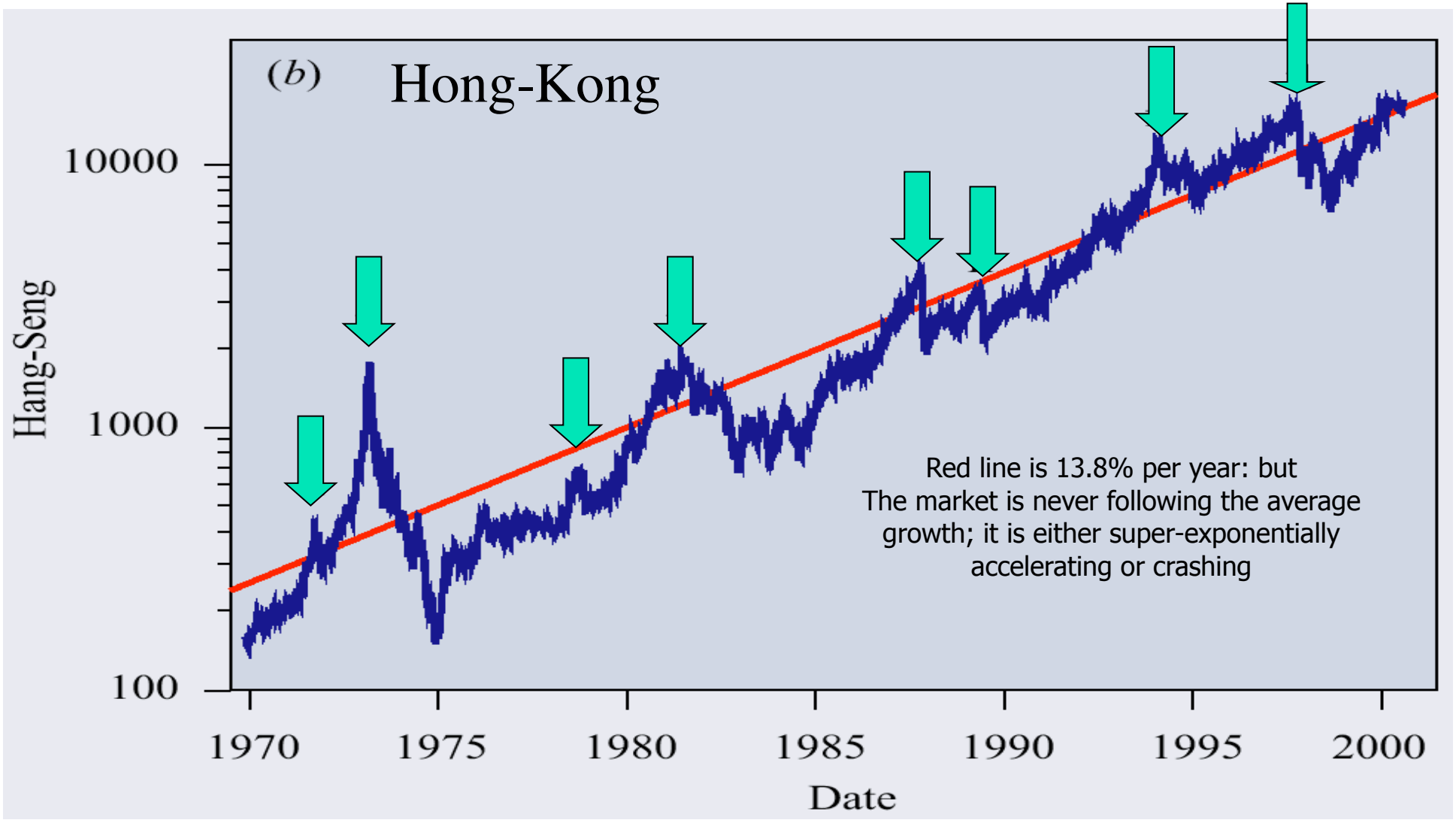
Instead of
Water Level:
-economic index
(Dow-Jones etc…)



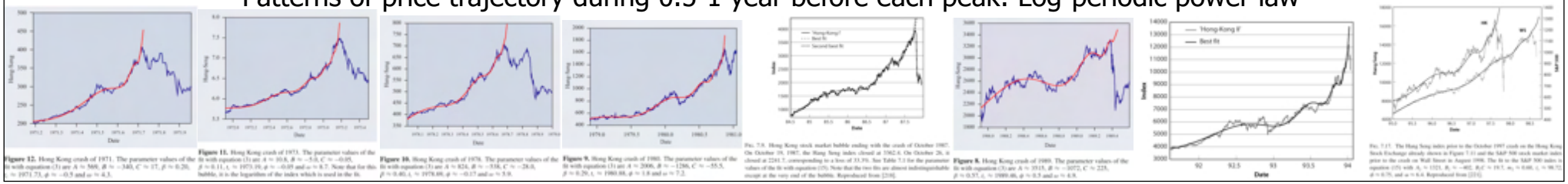
Crash = result of collective behavior of individual traders

(S. Solomon)

Financial Instability Hypothesis (Minsky)



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

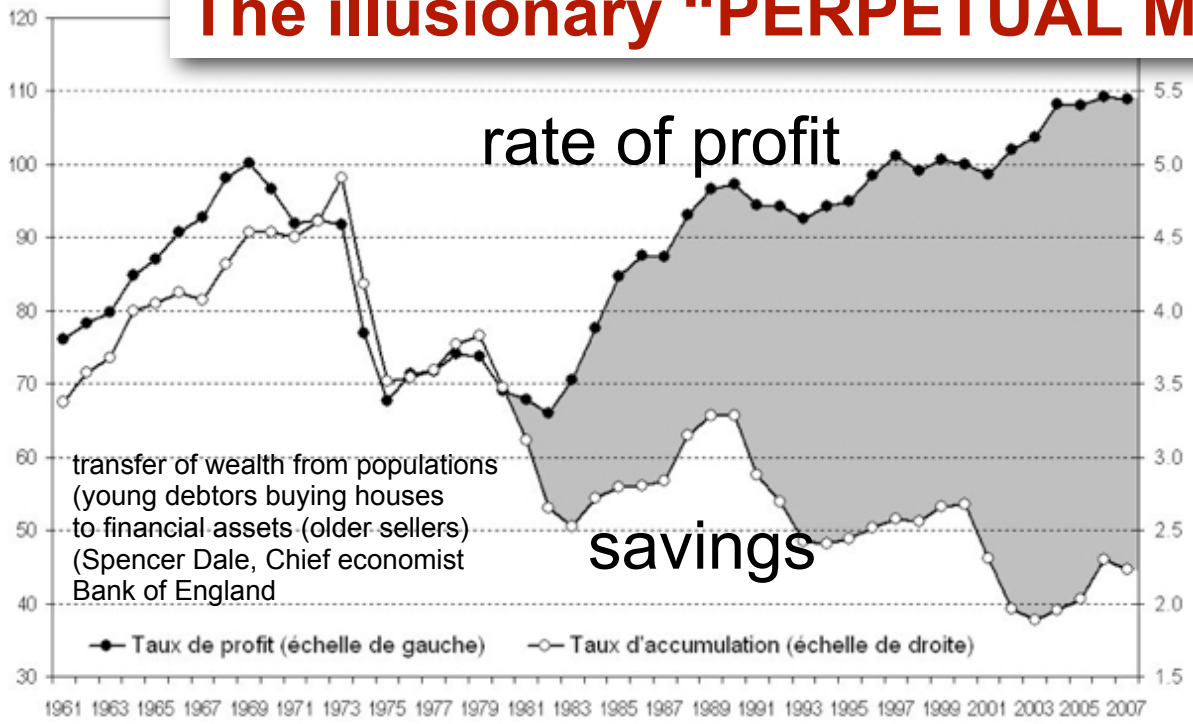


Predictability of the 2007-XXXX crisis: 15y History of bubbles and Dragon-kings

- The ITC “new economy” bubble (1995-2000)
- Slaving of the Fed monetary policy to the stock market descent (2000-2003)
- Real-estate bubbles (2003-2006)
- MBS, CDOs bubble (2004-2007)
- Stock market bubble (2004-2007)
- Commodities and Oil bubbles (2006-2008)

Didier Sornette and Ryan Woodard
Financial Bubbles, Real Estate bubbles, Derivative Bubbles, and the Financial and Economic Crisis (2009)
(http://arxiv.org/abs/0905.0220)

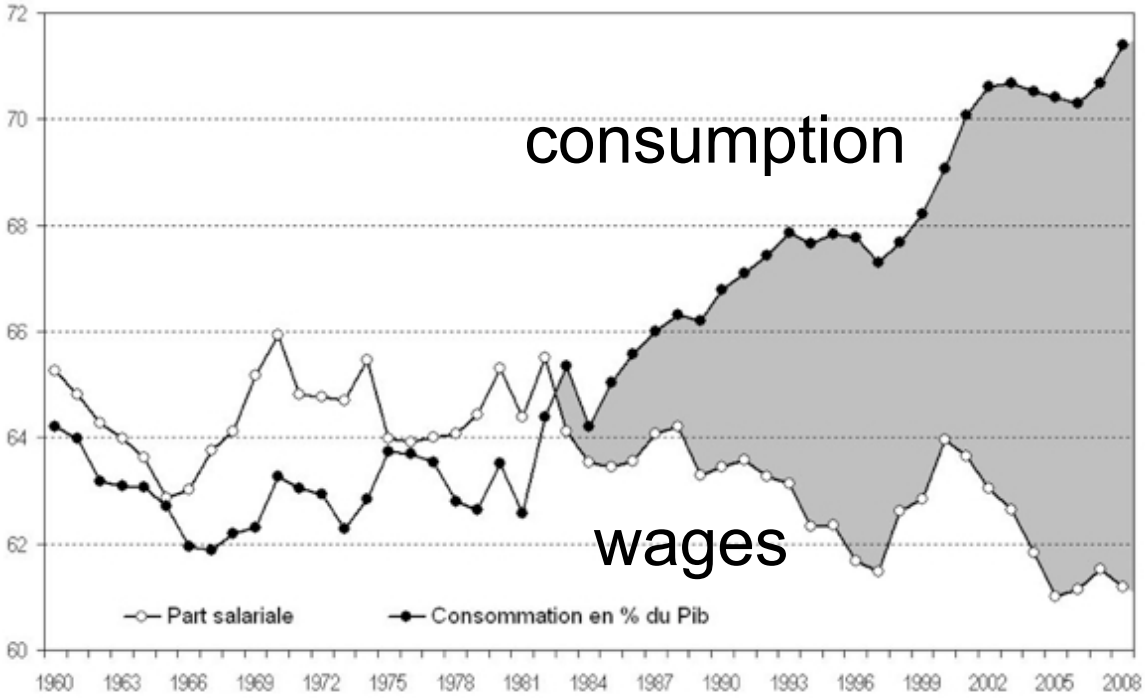
The illusionary "PERPETUAL MONEY MACHINE"



Rate of profit and rate of accumulation: The United States + European Union + Japan

* Rate of accumulation = rate of growth rate of the net volume of capital * Rate of profit = profit/ capital (base: 100 in 2000)

Sources and data of the graphs: http://hussonet.free.fr/toxicap.xls



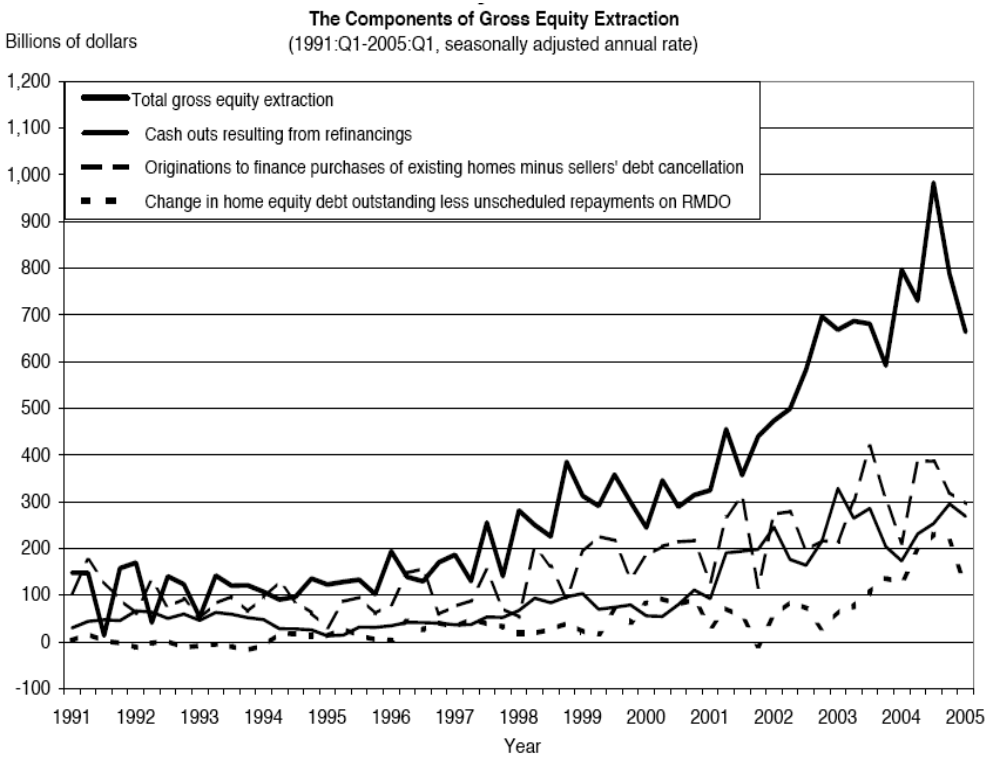
Thee gap widens between the share of wages and the share of consumption (gray zones), so as to compensate for the difference between profit and accumulation. FINANCE allows increasing debt and virtual wealth growh... which can only be transitory (even if very long).

United States Share of wages and of private consumption in Gross Domestic Product (GDP)

Source of data and graphics: http://hussonet.free.fr/toxicap.xls

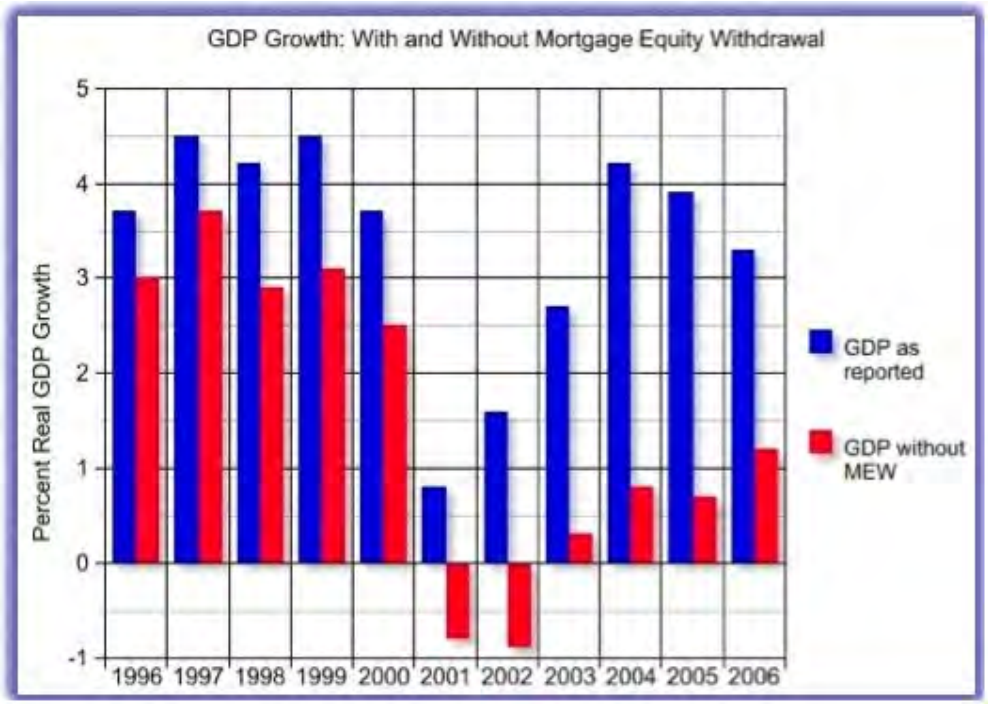
Wealth Extraction

Over the past decade and a half, (B - F) has been closely correlated with realized capital gains on the sale of homes. B-F=change in home equity debt outstanding less unscheduled repayment on RMDO



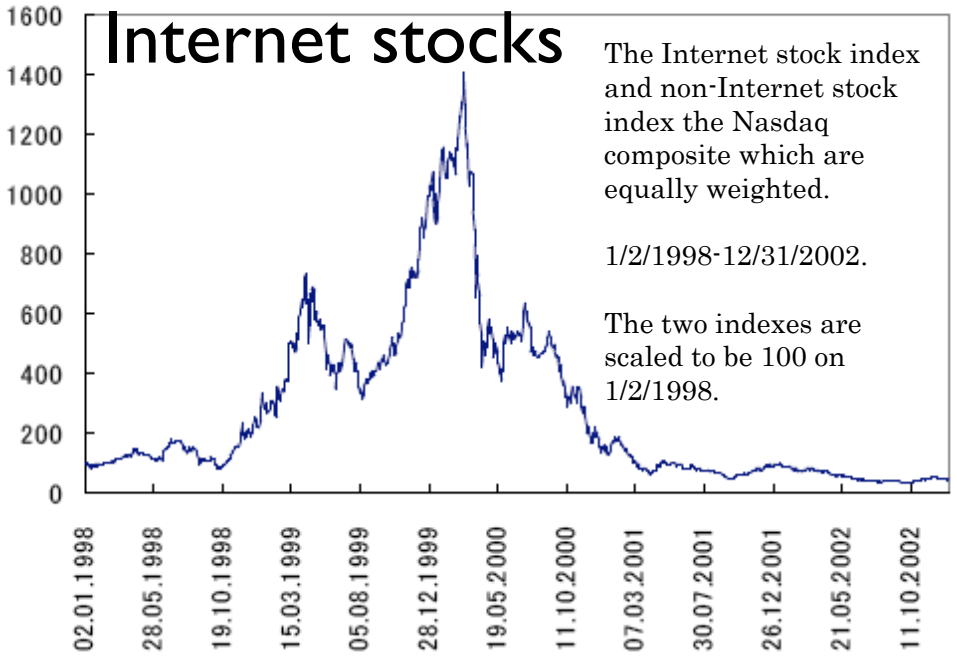
Alan Greenspan and James Kennedy (Nov. 2005)

Mortgage Equity Withdrawal impact on GDP

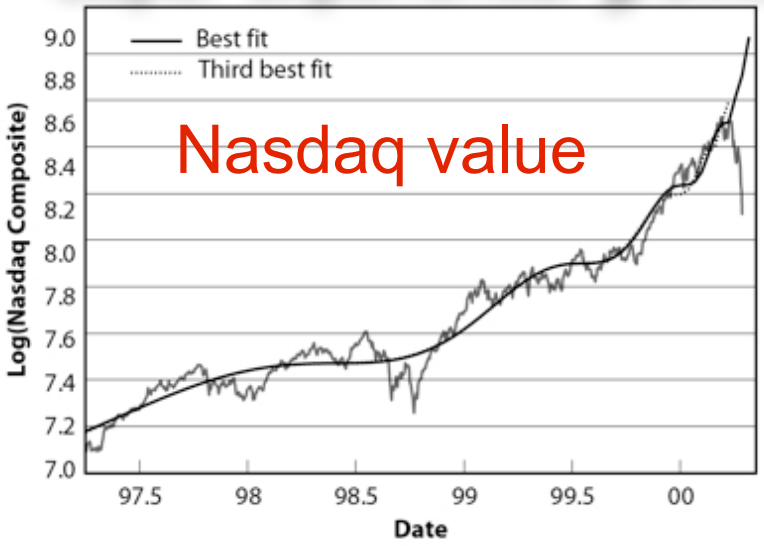


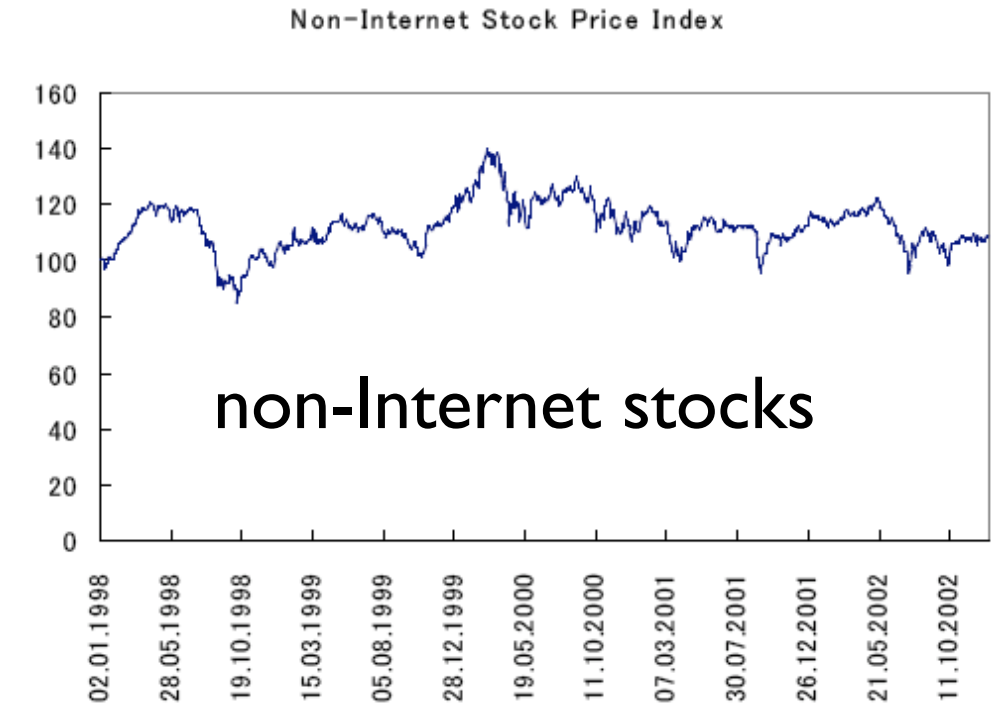
source: John Mauldin (April 09)

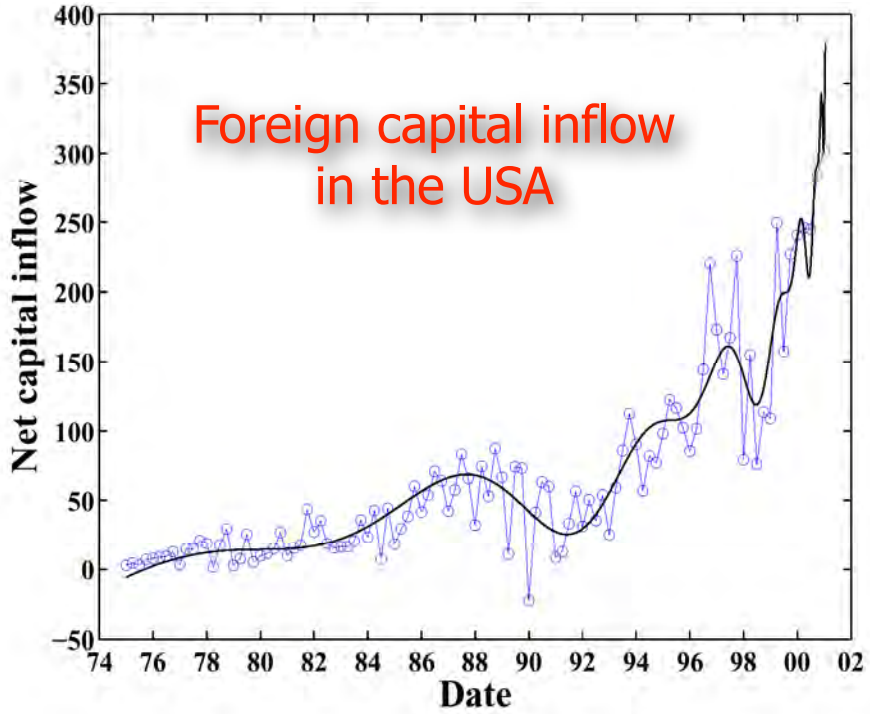
THE NASDAQ CRASH OF APRIL 2000

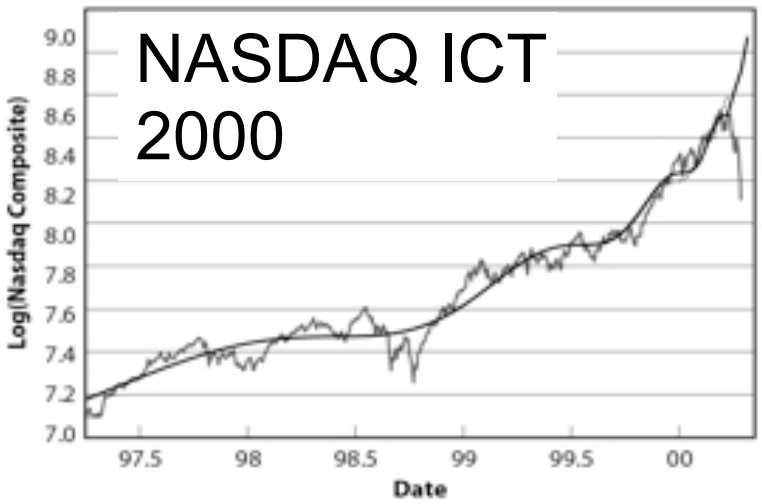


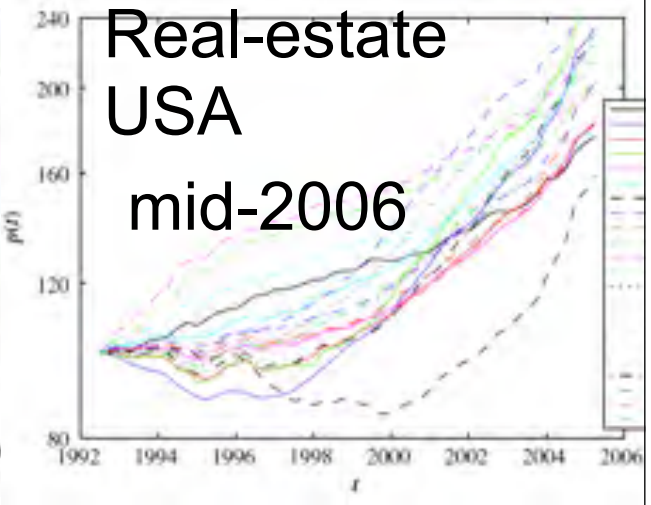
Super-exponential growth



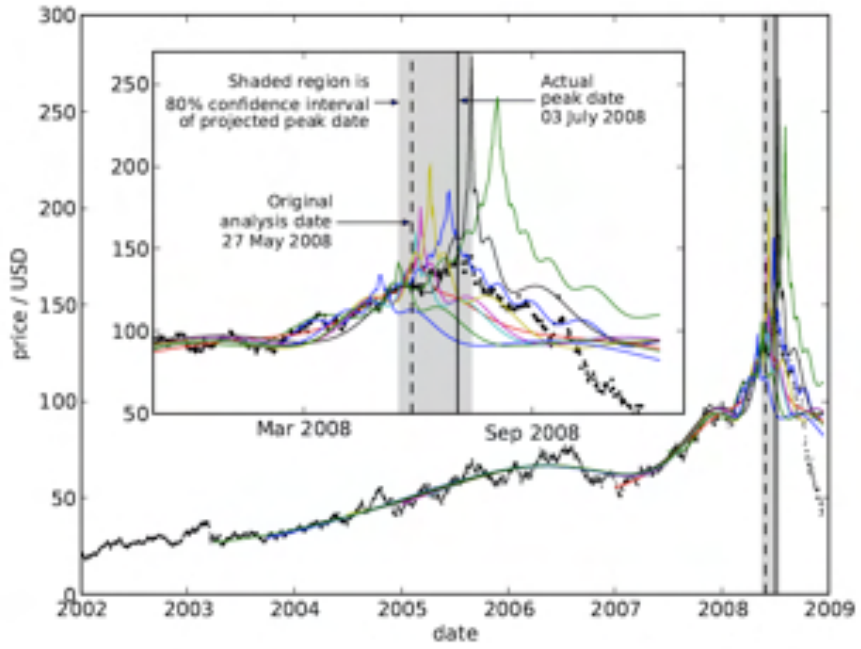




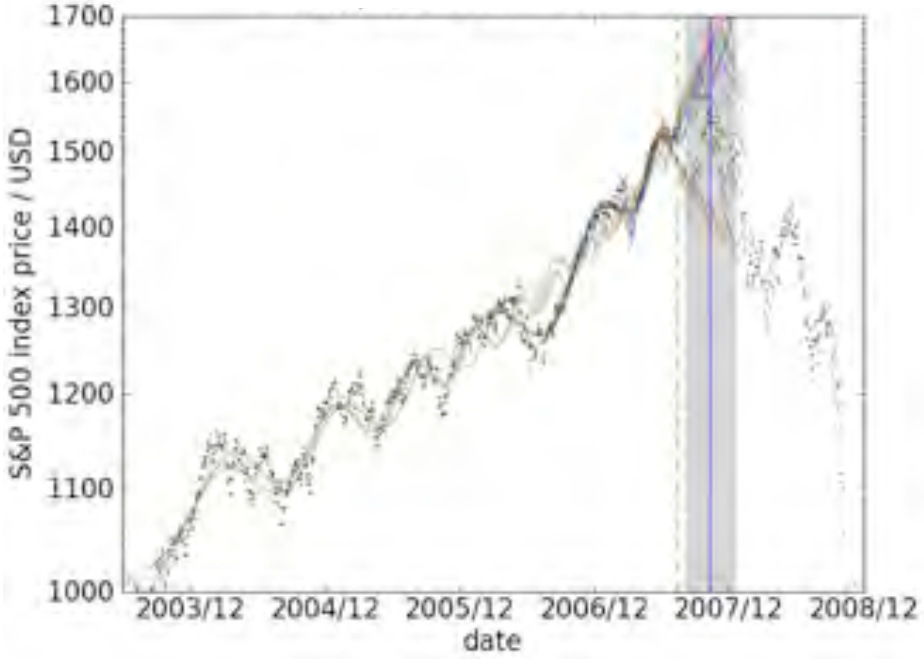


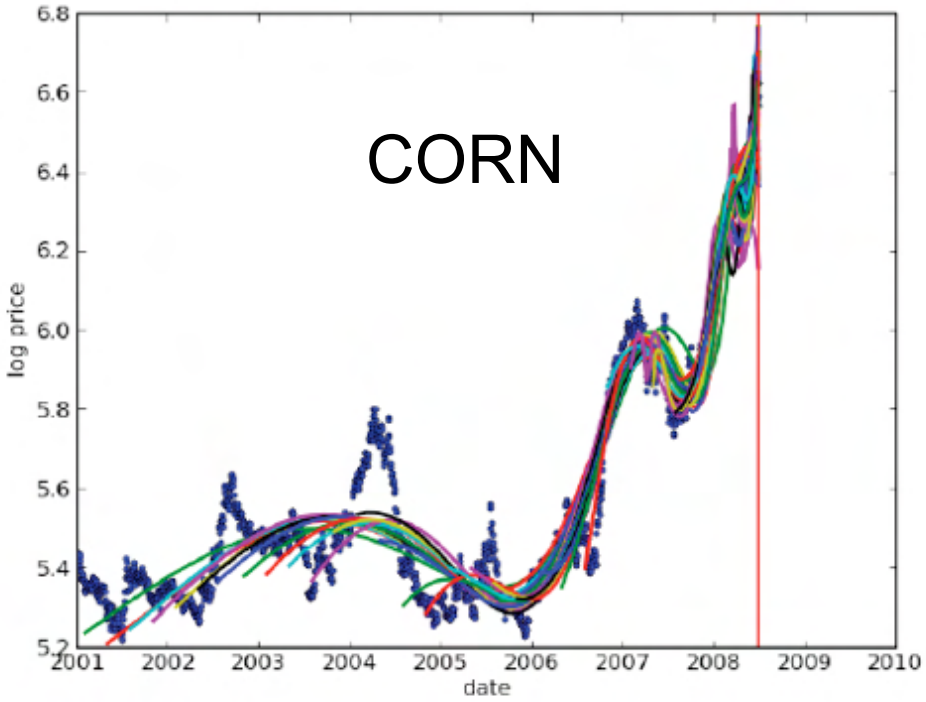


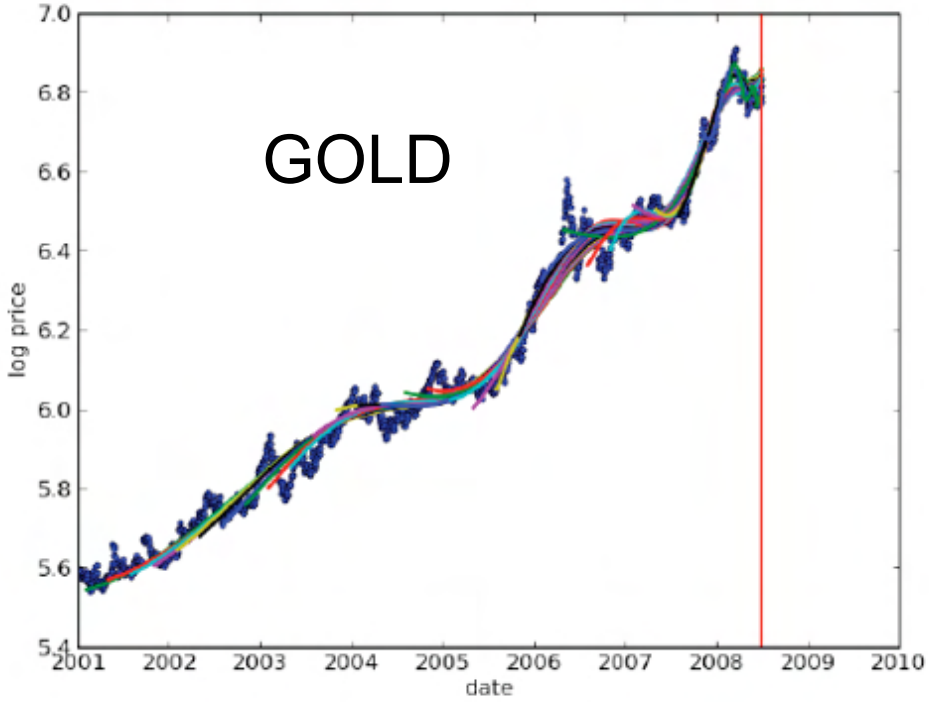
Oil July 2008



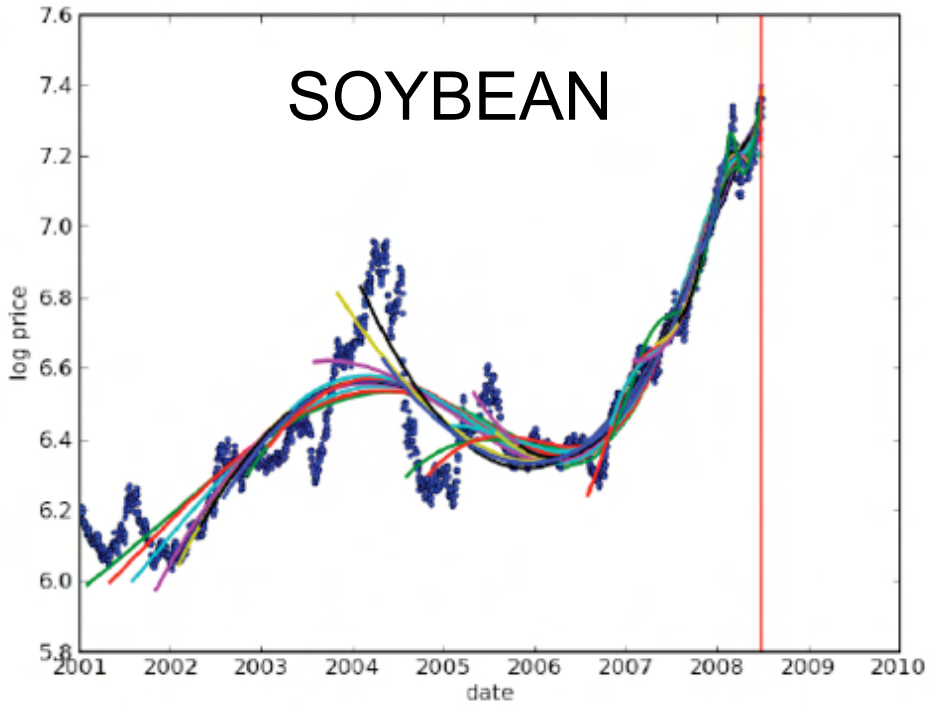
S&P500 USA Oct. 2007

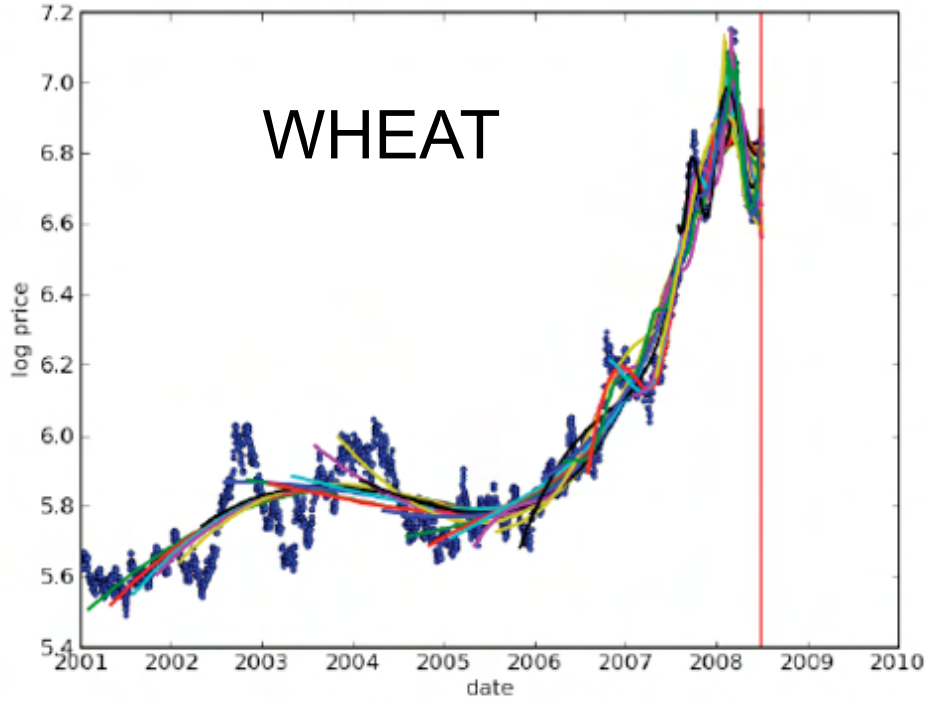




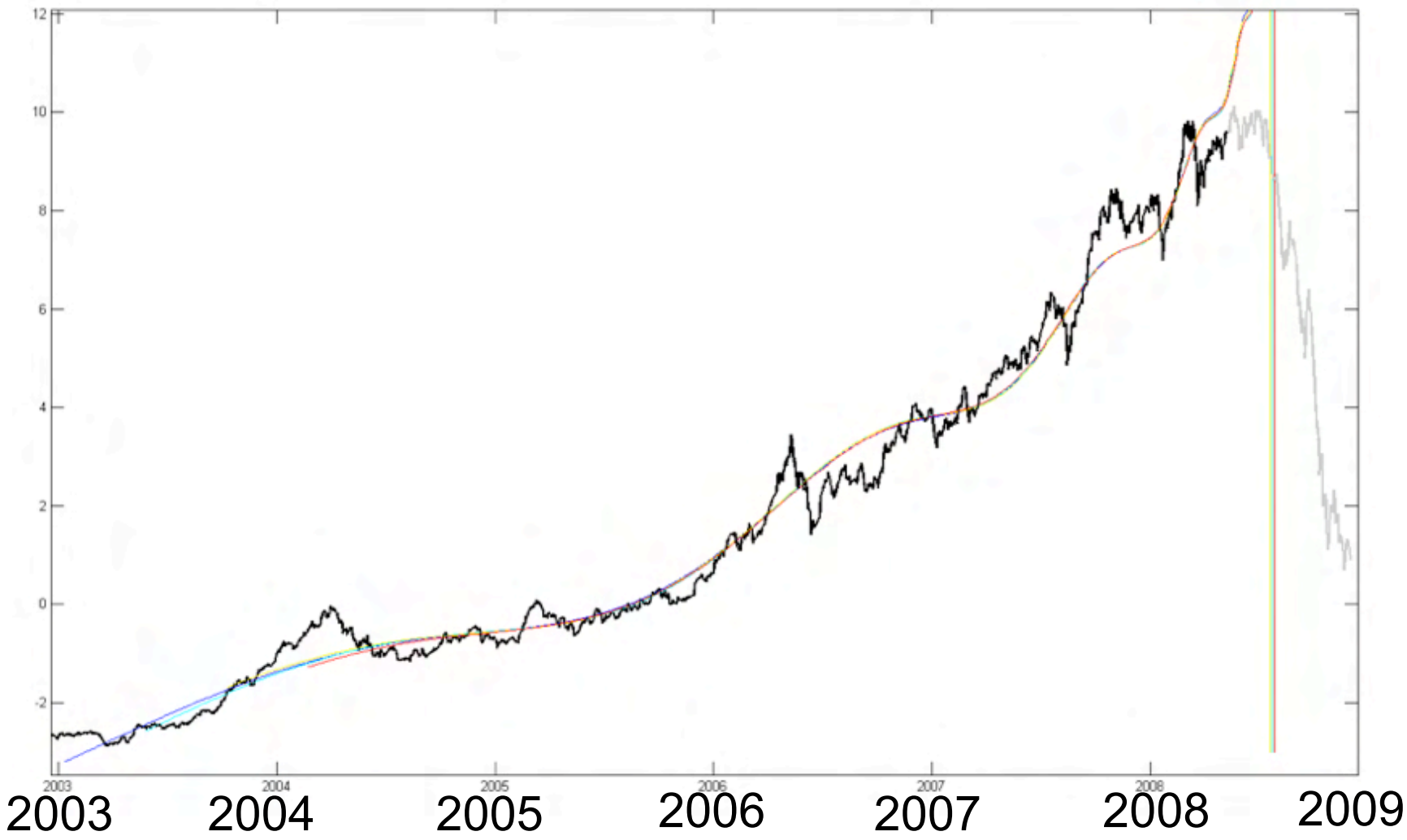


R.Woodard and D.Sornette (2008)





The Global BUBBLE



PCA first component on a data set containing, emerging markets equity indices, freight indices, soft commodities, base and precious metals, energy, currencies...

(Peter Cauwels FORTIS BANK - Global Markets)

New risks to consider

- Inflation and Deflation
- Bank failures
- “Government risks”
- Economic Slowdown (China)

•Financial instabilities are developing everywhere and will develop even more than in the past.

•Systemic risks are rising planet-wise, with entangling of many risk components (everything is linked).

Towards new asset allocation strategies

1- Fundamental allocation

-strategic allocation in energy, environment, commodities...

2- Tactical allocation

-Bubble diagnostic (targeted, scanning, global...)

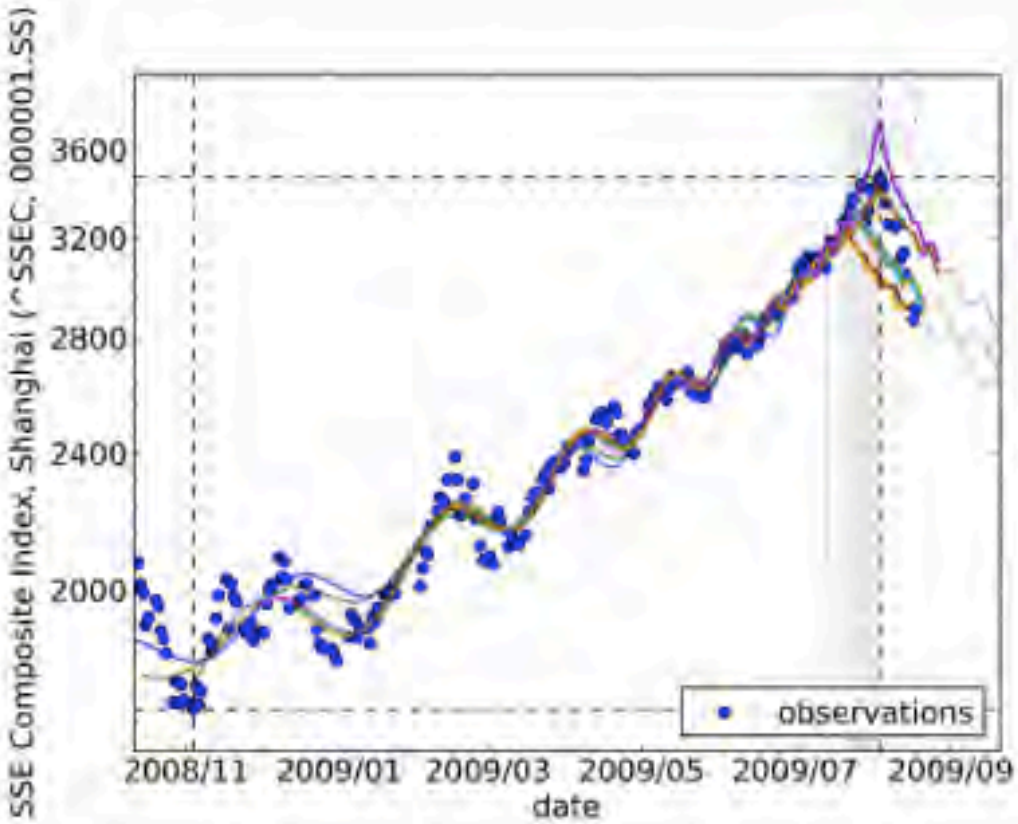
-Global and local crash alarm indices

-Improved timing (TaR: Time @ Risk)

FCO@ETH: Towards operational science of financial instabilities

Didier Sornette, Maxim Fedorovsky, Stefan Riemann, Hilary Woodard, Ryan Woodard, Wanfeng Yan, Wei-Xing Zhou

- Main mission:
  - Identify bubbles
- Theory:
  - Positive feedback
- Deliverables
  - Weekly global bubble scan
  - Research, papers
  - Public forecasts
  - Digital timestamps



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Department Management, Technology and Economics
MTEC

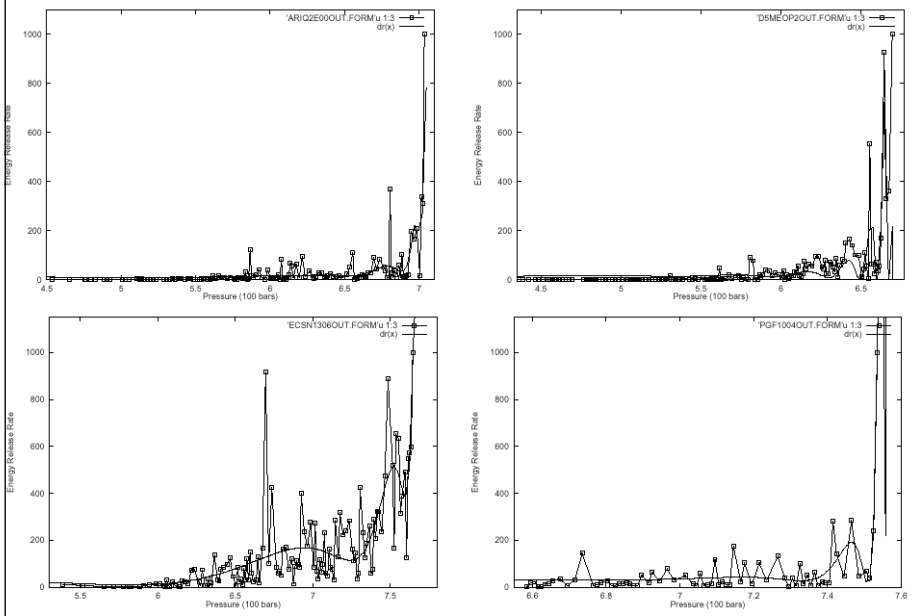
Entrepreneurial Risks

The Financial Bubble Experiment
First Results (2 November 2009 - 3 May 2010)

D. Sornette, R. Woodard, M. Fedorovsky, S. Reimann, H. Woodard, W.-X. Zhou
(The Financial Crisis Observatory)
Department of Management, Technology and Economics,
ETH Zurich, Kreuzplatz 5, CH-8032 Zurich, Switzerland

Methodology for predictability of crises

Strategy: look at the forest rather than at the tree



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)

Methodology for diagnosing bubbles

Inputs:

-prices

-factors (interest rates, interest spread, historical and implied volatility, exchange rates)

Methods:

-Self-consistent calibration of prices (not returns)

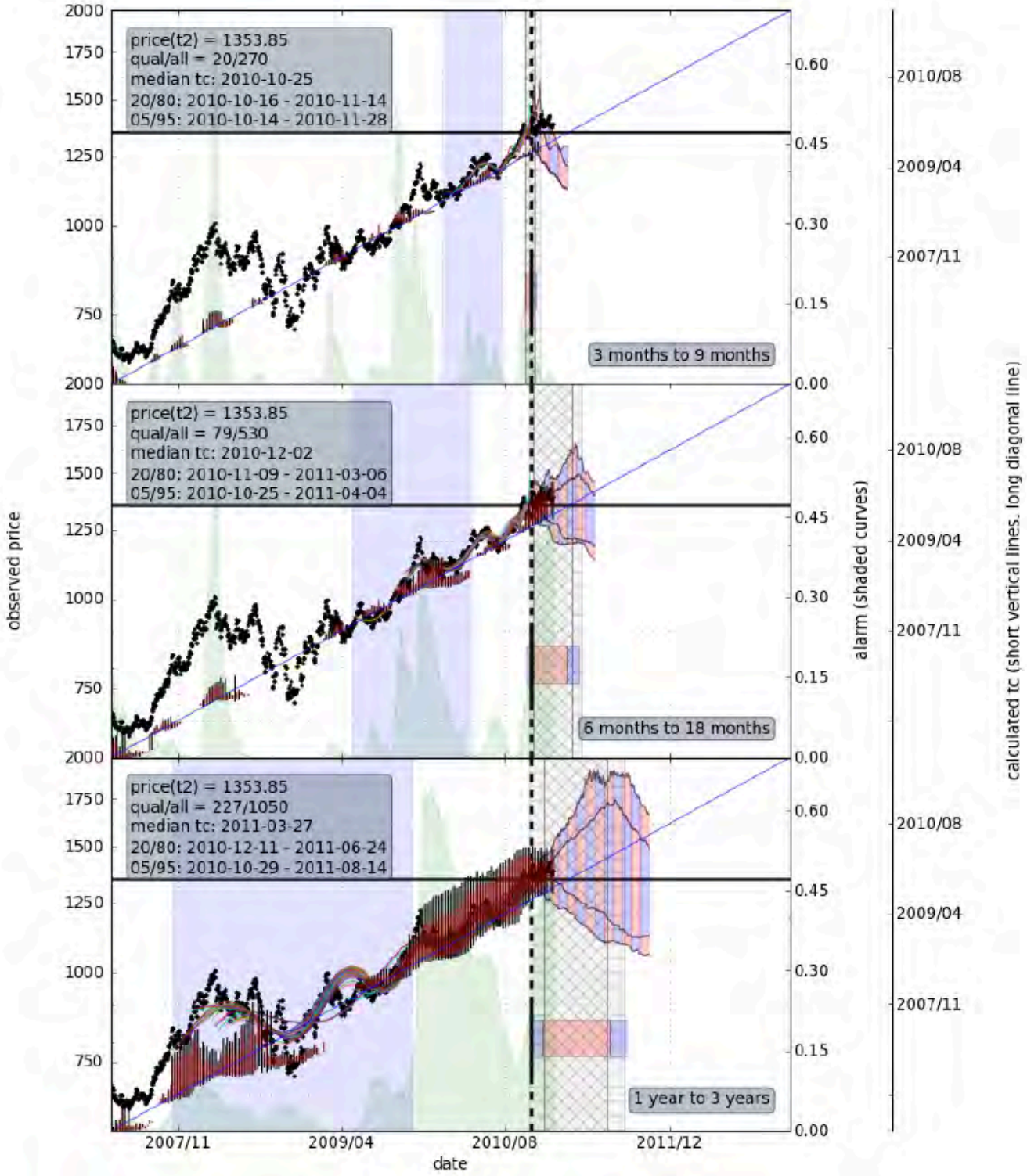
-Portolio of methods to identify transient bubble regimes (entropy, hierarchical analysis, reverse engineering with ABM...)

Methodology for diagnosing bubbles

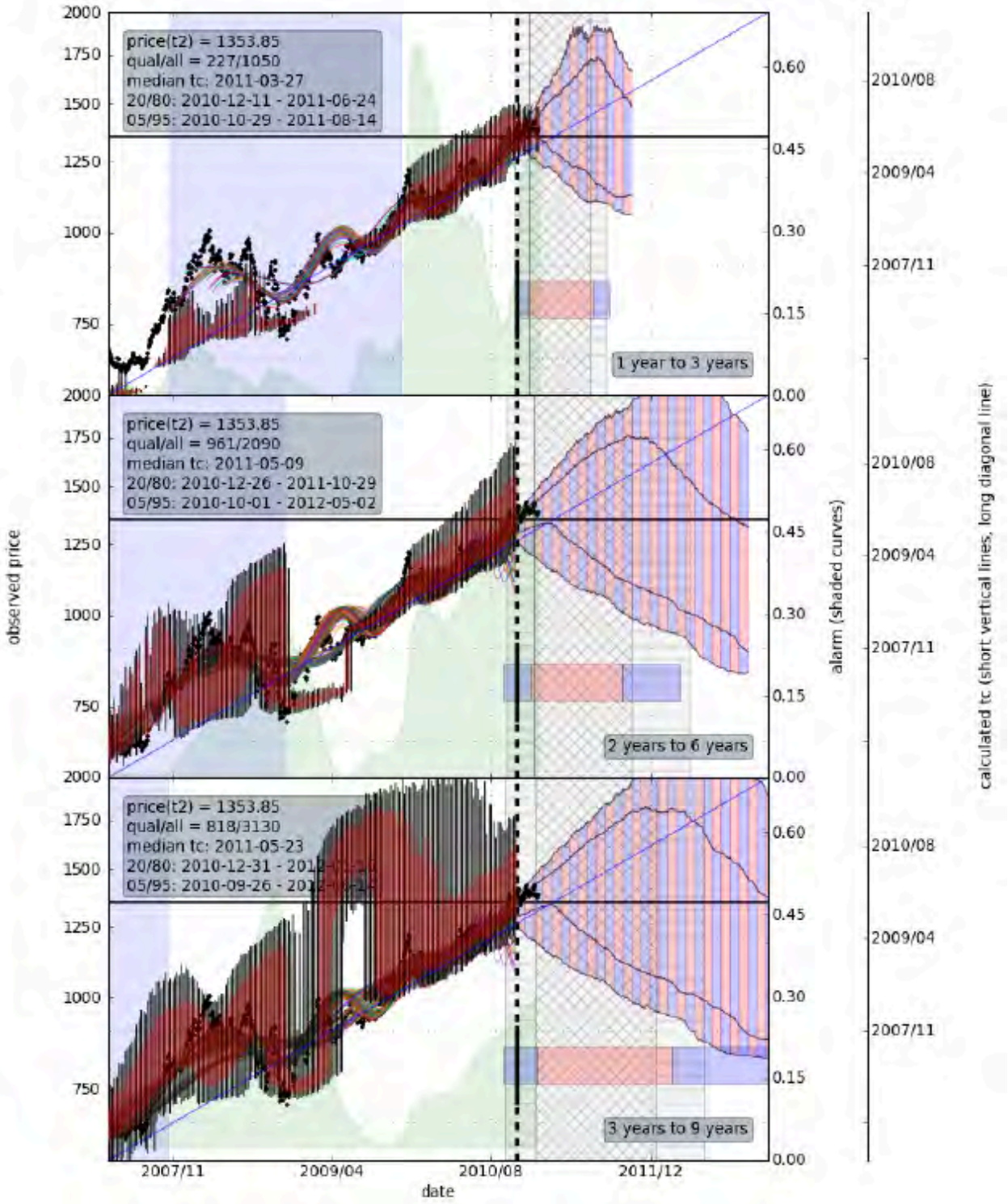
- Positive feedbacks of higher return anticipation
  - ✳Super exponential price
  - ✳Power law “Finite-time singularity”

- Negative feedback spirals of crash expectation
  - ✳Accelerating large-scale financial volatility
  - ✳Log-periodic discrete scale-invariant patterns

GOLD SPOT
USD
11 Jan 2011



GOLD SPOT USD



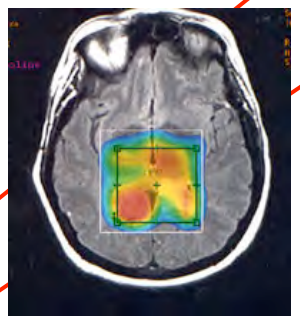
Generic Prediction Phase Diagram

Interaction (coupling) strength

By classifying a system in a given regime, we can assert its degree of predictability.

SYNCHRONIZATION
EXTREME RISKS

Coexistence of SOC
and Synchronized behavior



SELF-ORGANIZED CRITICALITY

INCOHERENT

10
1
0.1
0.01
0.001

0.001 0.01 0.1 1 10

Heterogeneity - diversity

Black Swans, Dragons-Kings and Prediction

- An illustration of trans-disciplinarity at work
- Out-of-equilibrium view of the world (social systems, economics, geosciences, biology...)
- Dragon-kings as extreme events are the rule rather than the exception. Their study reveal important new mechanisms.
- Crises are (probabilistically) predictable

Final remarks

1-All proposals will fail if we do not have better science and better metrics to monitor and diagnose (ex: biology, medicine, astronomy, chemistry, physics, evolution, and so on)

2-Leverage as a system variable versus the illusion of control by monetary policy, risk management, and all that

3-Need to make endogenous policy makers and regulators ("creationist" view of government role, illusion of control and law of unintended consequences of regulations)

4-Fundamental interplay between system instability and growth; the positive side of (some) bubbles

5-Time to reassess goals (growth vs sustainability vs happiness). In the end, endogenous co-evolution of culture, society and economy

KEY CHALLENGE: genuine trans-disciplinarity by

TRAINING in 2-3 disciplines + CHANGE OF CULTURE

Further Reading

T. Kaizoji and D. Sornette, Market Bubbles and Crashes, in press in the Encyclopedia of Quantitative Finance (Wiley, 2008)
(preprint at http://arxiv.org/abs/0812.2449)

D. Sornette and R. Woodard Financial Bubbles, Real Estate bubbles, Derivative Bubbles, and the Financial and Economic Crisis
(preprint at http://arxiv.org/abs/0905.0220) will appear in the Proceedings of APFA7 (Applications of Physics in Financial Analysis, http://www.thic-apfa7.com/en/htm/index.html)

Didier Sornette, Why Stock Markets Crash
(Critical Events in Complex Financial Systems)
Princeton University Press, January 2003

Y. Malevergne and D. Sornette, Extreme Financial Risks (From Dependence to Risk Management) (Springer, Heidelberg, 2006).