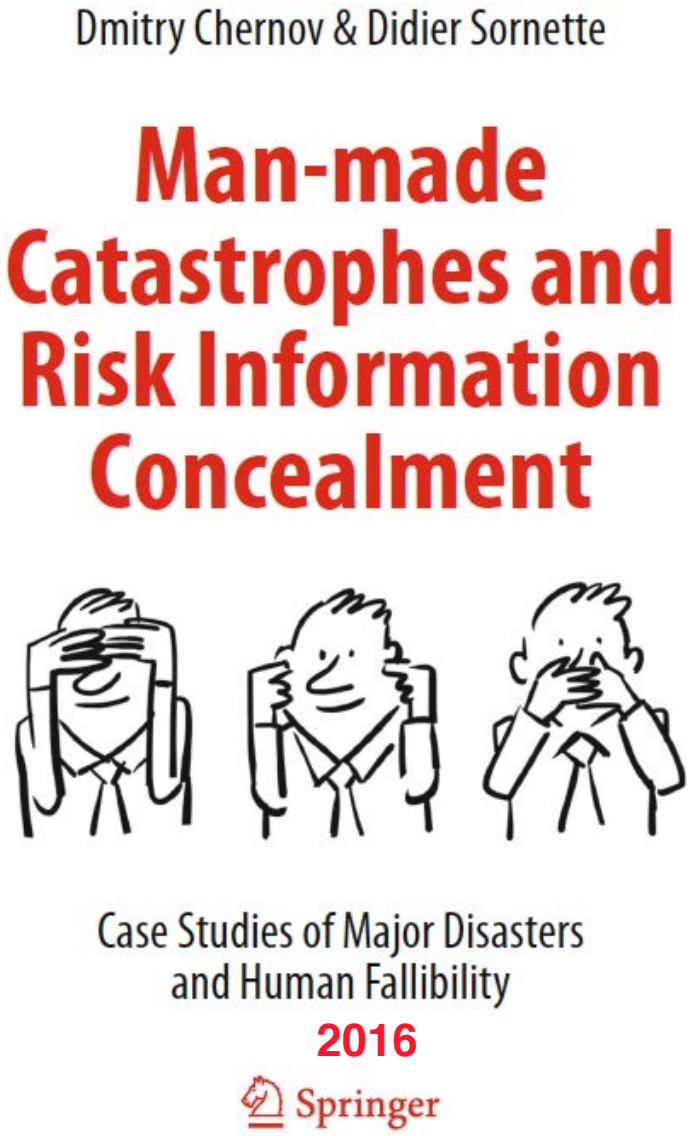
ETH Zurich
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

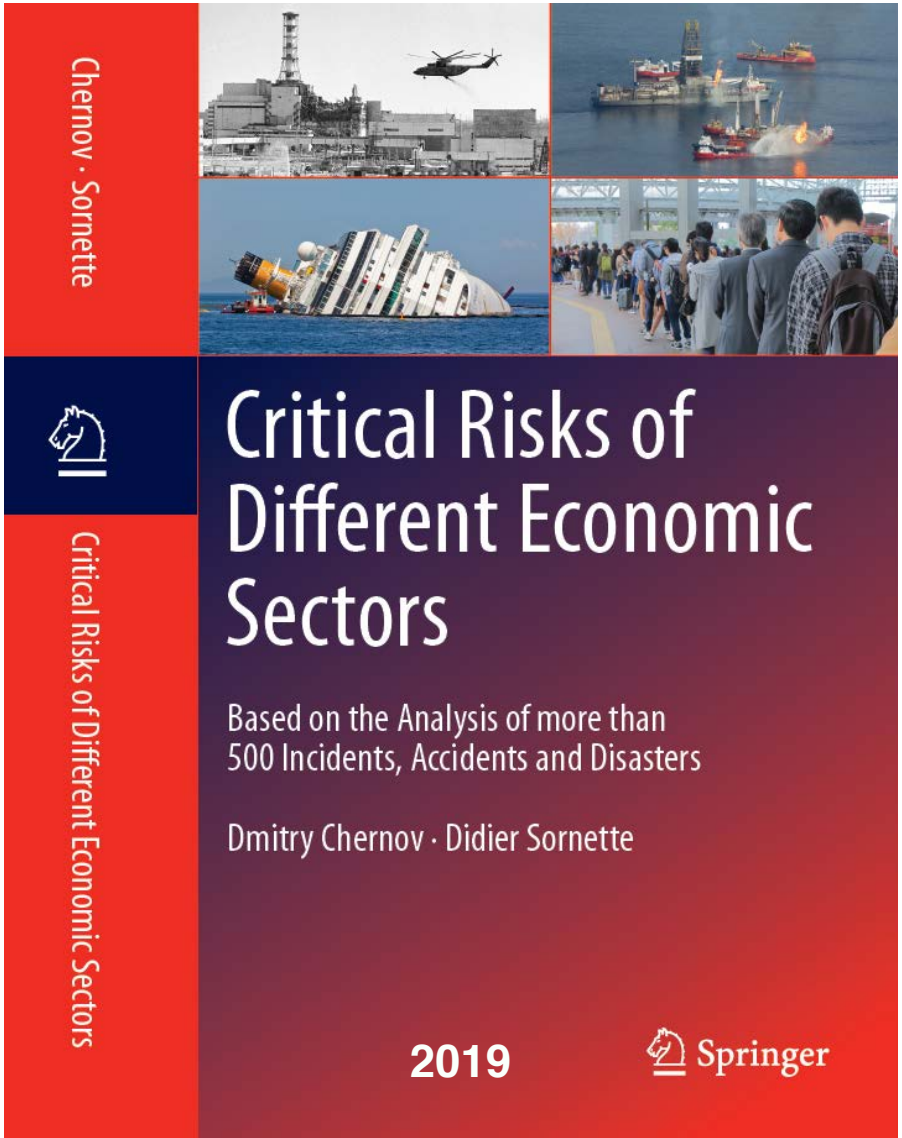
Entrepreneurial Risks

南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Dynamical risk management: prediction and adaptation to a wild world

Didier SORNETTE
www.er.ethz.ch





Failure of management

- lack of courage and laziness to address the real problems (status quo, lack of right incentives)

- **lack of understanding of the nature of complex systems**

- **lack of imagination to explore the relevant possible scenarios**

  "Nature is more imaginative than the best manager, engineer or mathematician!"

- lack of leadership to foster information transfer and communication, for communicating the vision, goals and targets

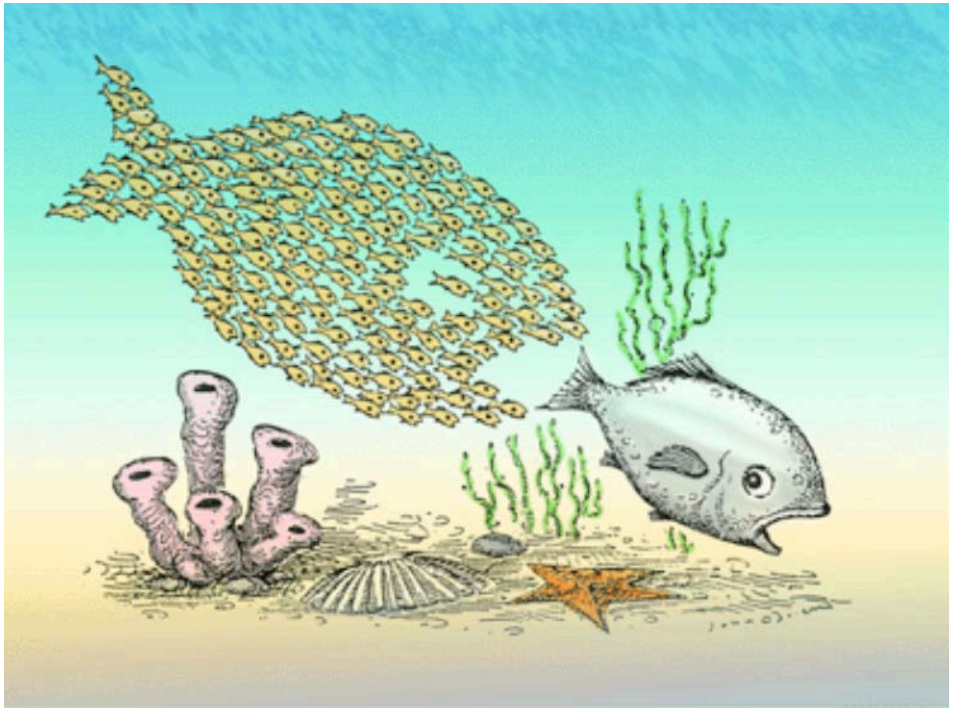
- **The fair reward problem: misguided incentives to reward success instead of process ("luck vs skill")**

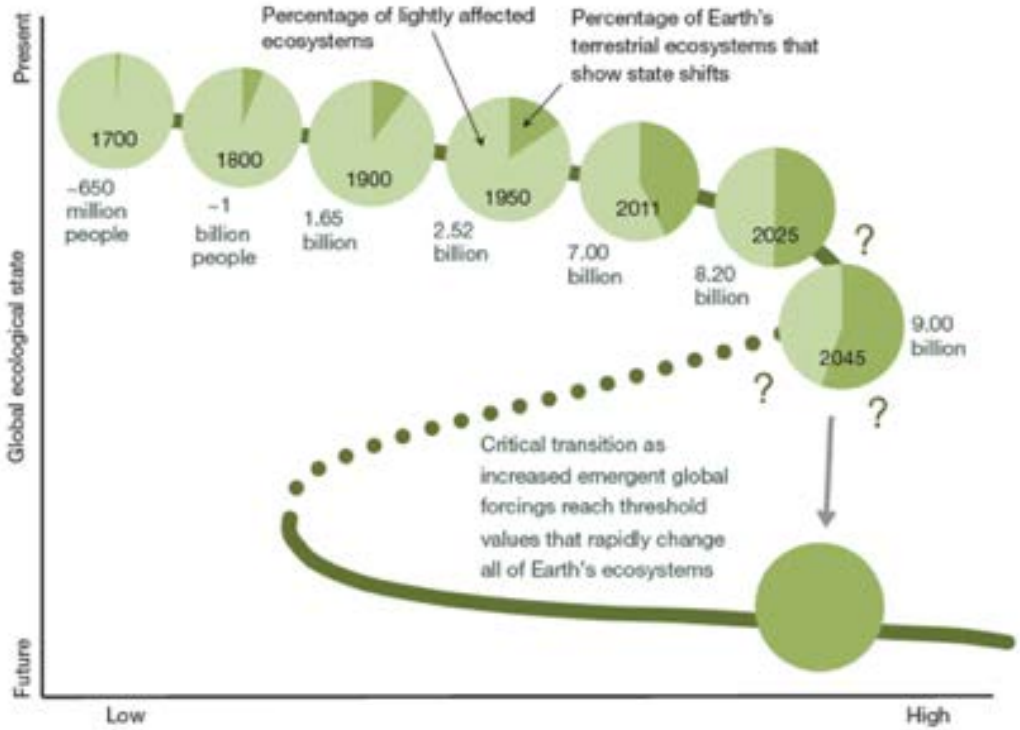
Nature of complex systems

emergence

regimes and transitions

health of our Planet

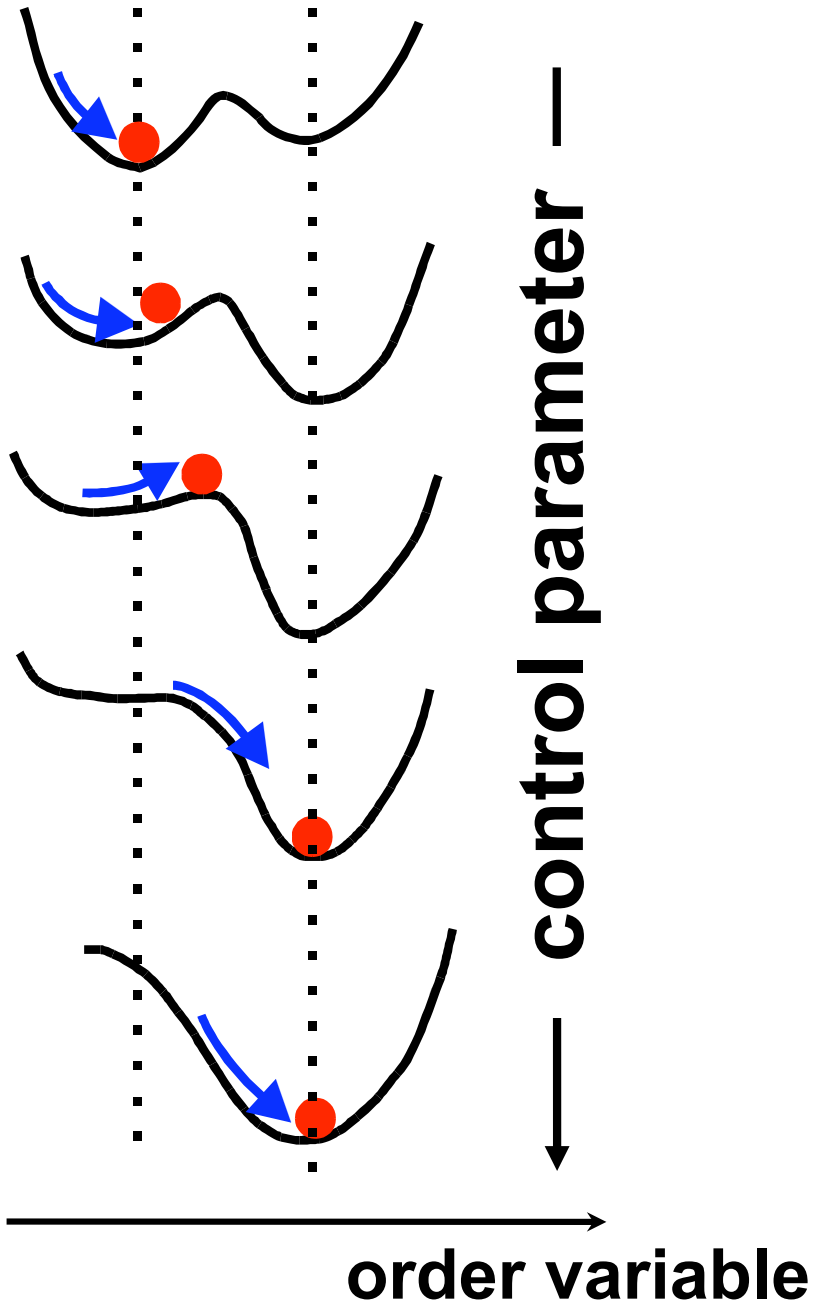




human footprint

Phase Transitions

Bifurcations can be explained as a change in a potential energy function similar to the change which occurs in a physical phase transition.

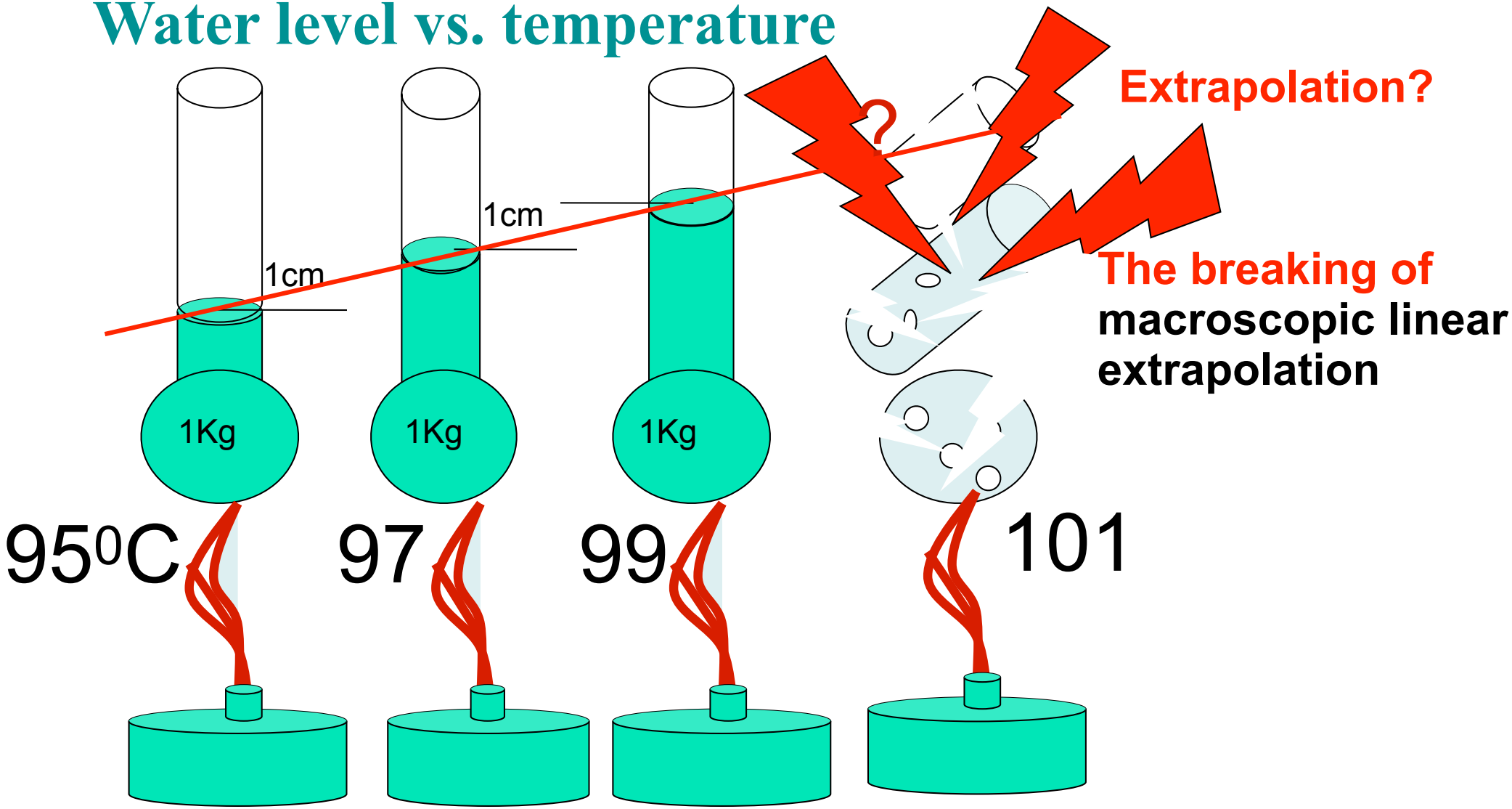


Haken 1983 *Synergetics: An Introduction* Springer-Verlag
Kelso 1995 *Dynamic Patterns* MIT Press

(after Liebovitch)

Changes often result from a progressive maturation towards an instability (bifurcation)

Water level vs. temperature

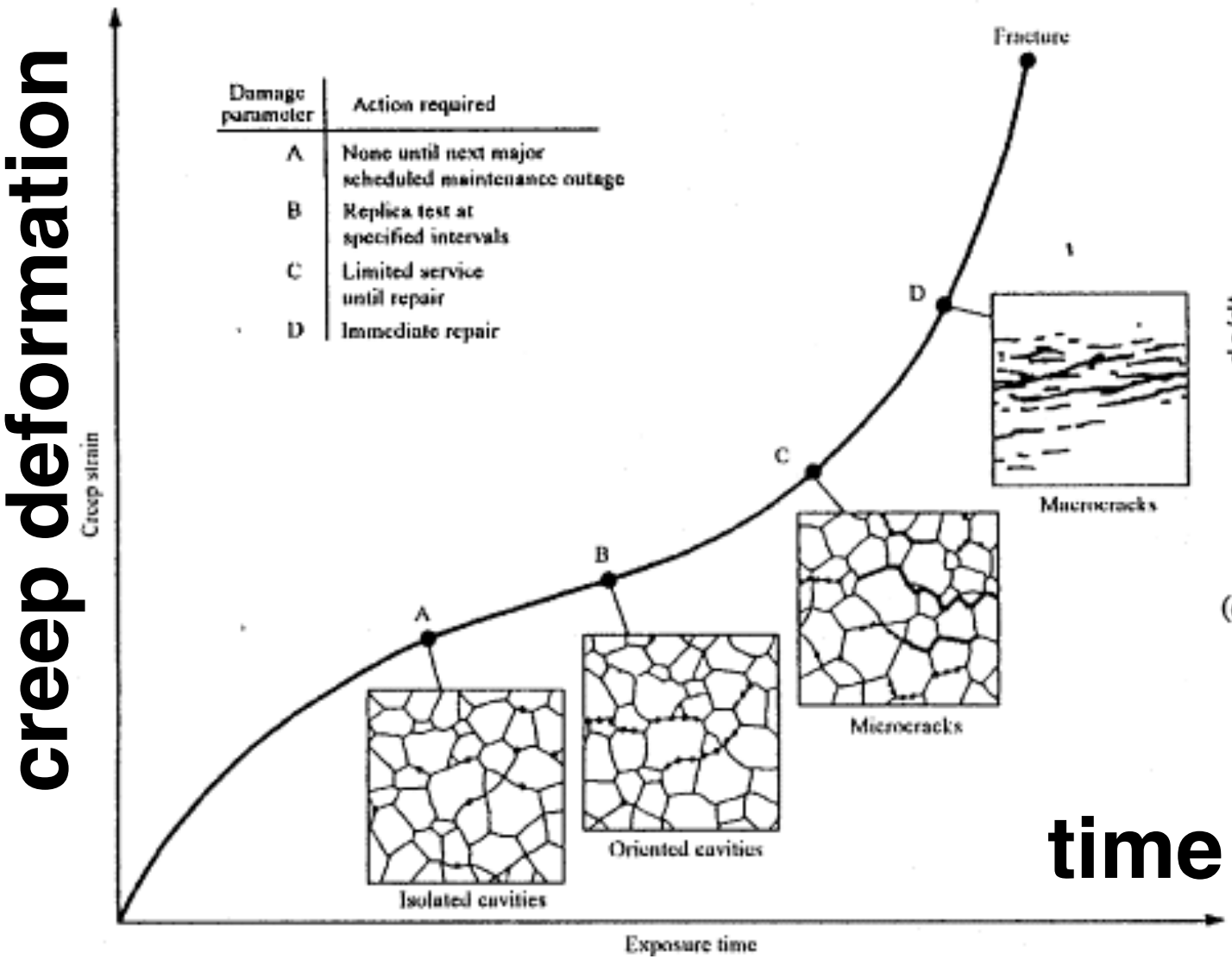


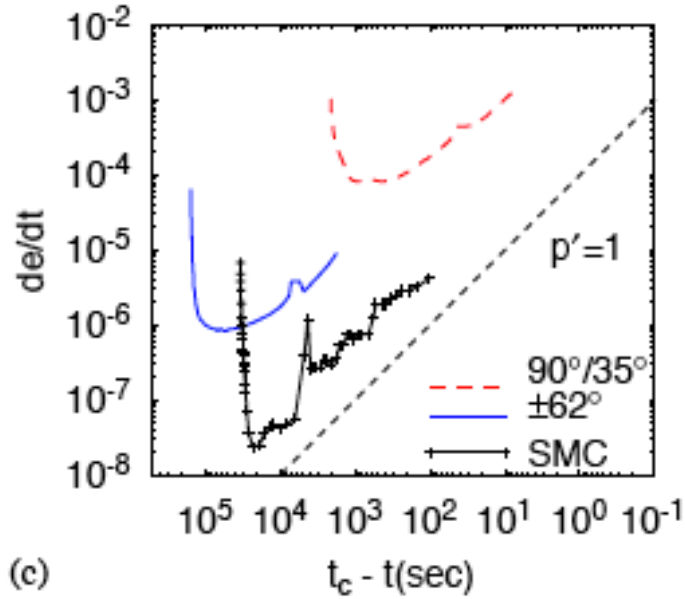
BOILING PHASE TRANSITION

More is different: a single molecule does not boil at 100C⁰

(S. Solomon)

Creep strain as a function of time





$$\frac{de}{dt} \sim \frac{1}{(t_c - t)^{p'}}$$

predictability via “finite-time singularity behavior

H. Nechad, A. Helmstetter, R. El Guerjouma and D. Sornette, Creep Ruptures in Heterogeneous Materials, Phys. Rev. Lett. 94, 045501 (2005) ; 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)

Fundamental reduction theorem

Generically, close to a regime transition, a system bifurcates through the variation of a SINGLE (or a few) effective "control" parameter

Bifurcation: Qualitative change in behavior as parameter is (slowly) varied

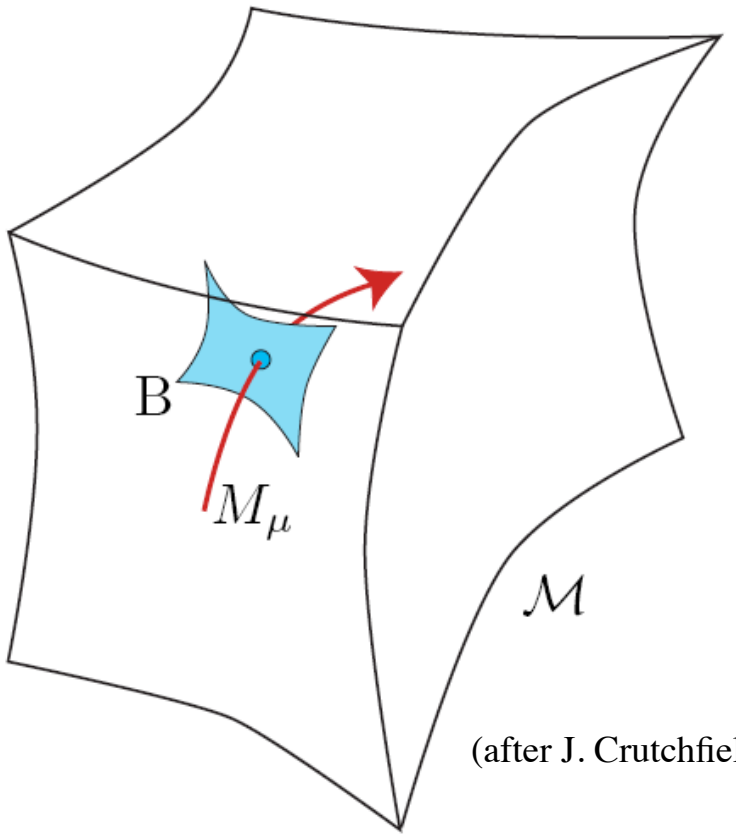
Bifurcation surface: B

Strategy 1: understand from proximity to a reference point as a function of a small parameter

Strategy 2: a few universal "normal forms"

Space of all dynamical systems: $\mathcal{M}$

a particular dynamical system: $M \in \mathcal{M}$



(after J. Crutchfield)

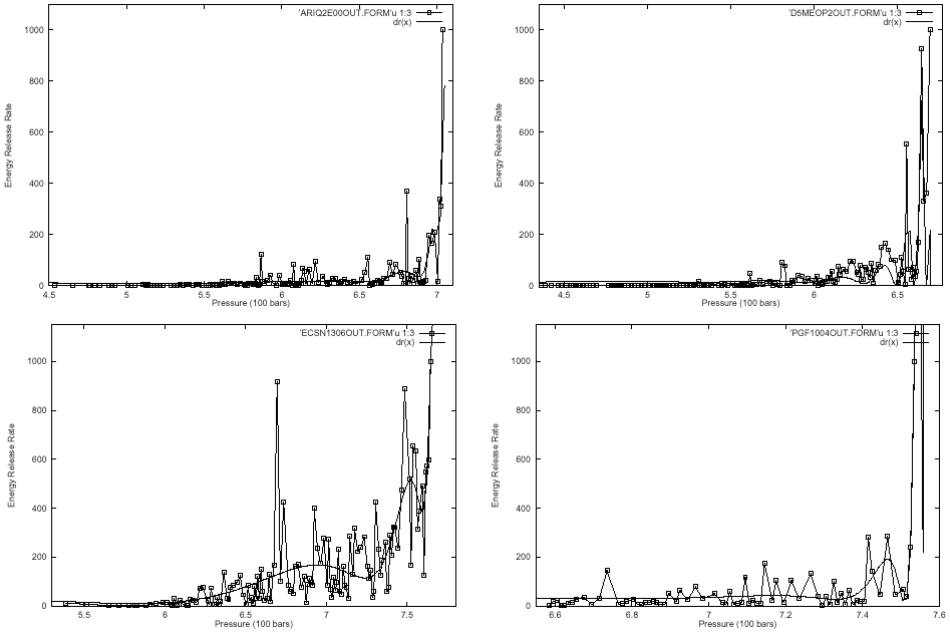
Signs of Upcoming transitions

Early warning signals as predicted from theory

- Slower recovery from perturbations
- Increasing (or decreasing) autocorrelation
- Increasing (or decreasing) cross-correlation with external driving
- Increasing variance
- Flickering and stochastic resonance
- Increased spatial coherence
- **Degree of endogeneity/reflexivity**
- **Super-exponential growth with positive feedbacks**

=> monitor trends and deviations!

Strategy: look at the forest rather than at the tree



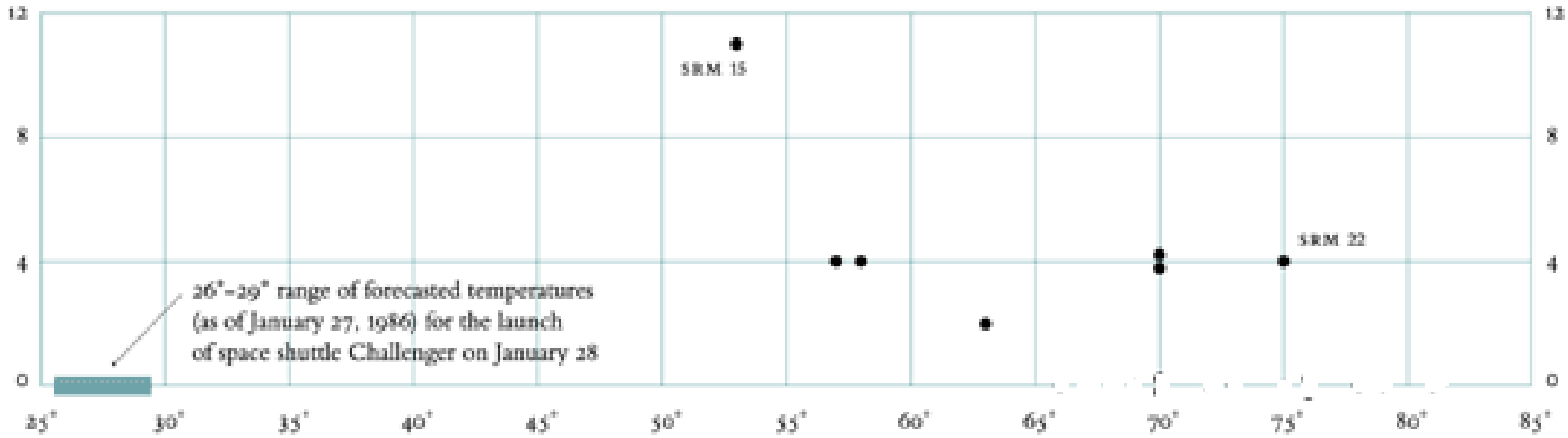
- Increasing variance
- Increased spatial coherence
- Finite-time singularity

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

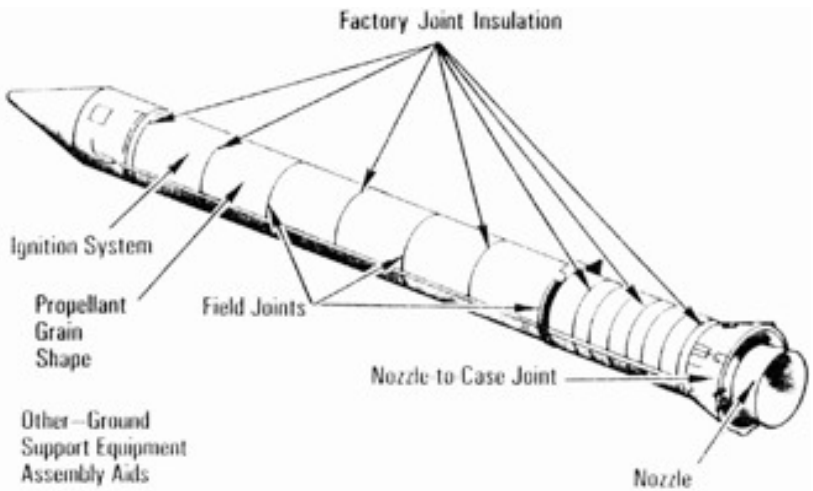
J.-C. Anifrani, C. Le Floc'h, D. Sornette and B. Souillard
"Universal Log-periodic correction to renormalization group scaling for rupture stress prediction from acoustic emissions", J.Phys.I France 5, n°6, 631-638 (1995)

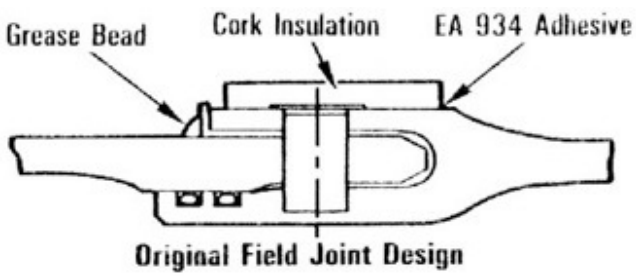
Shuttle Flight 51-L (Challenger) 1986

O-ring damage index (each launch)



temperature at take-off





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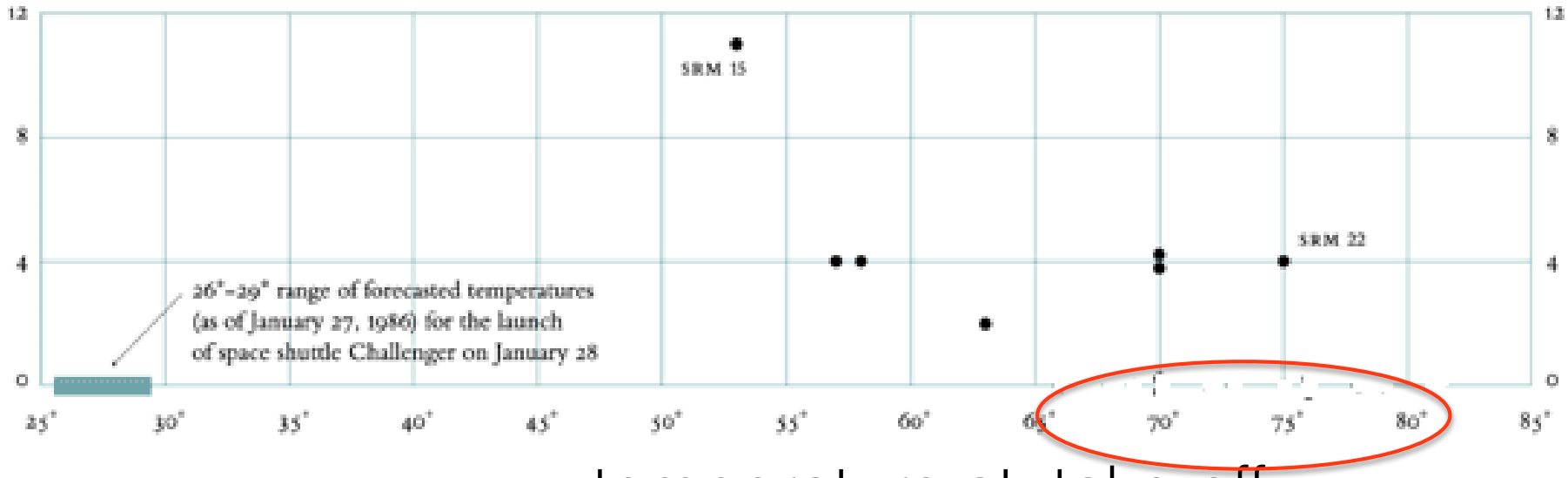
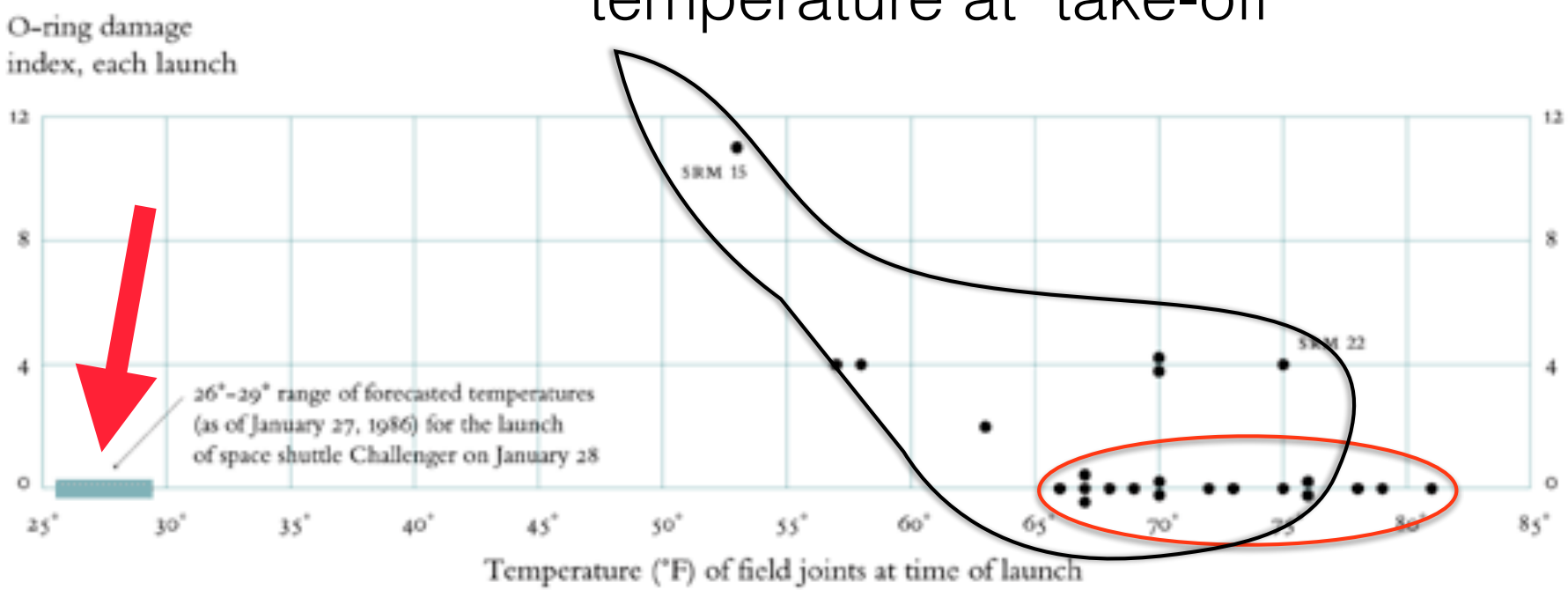
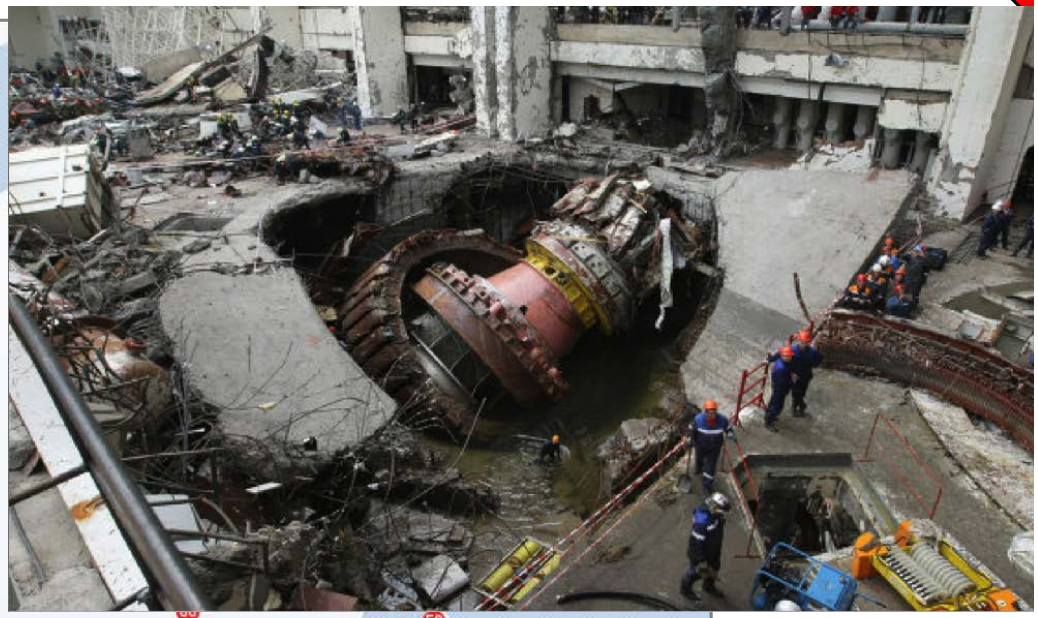




(E.R. Tufte)

Recovery costs >US $1.5 bln

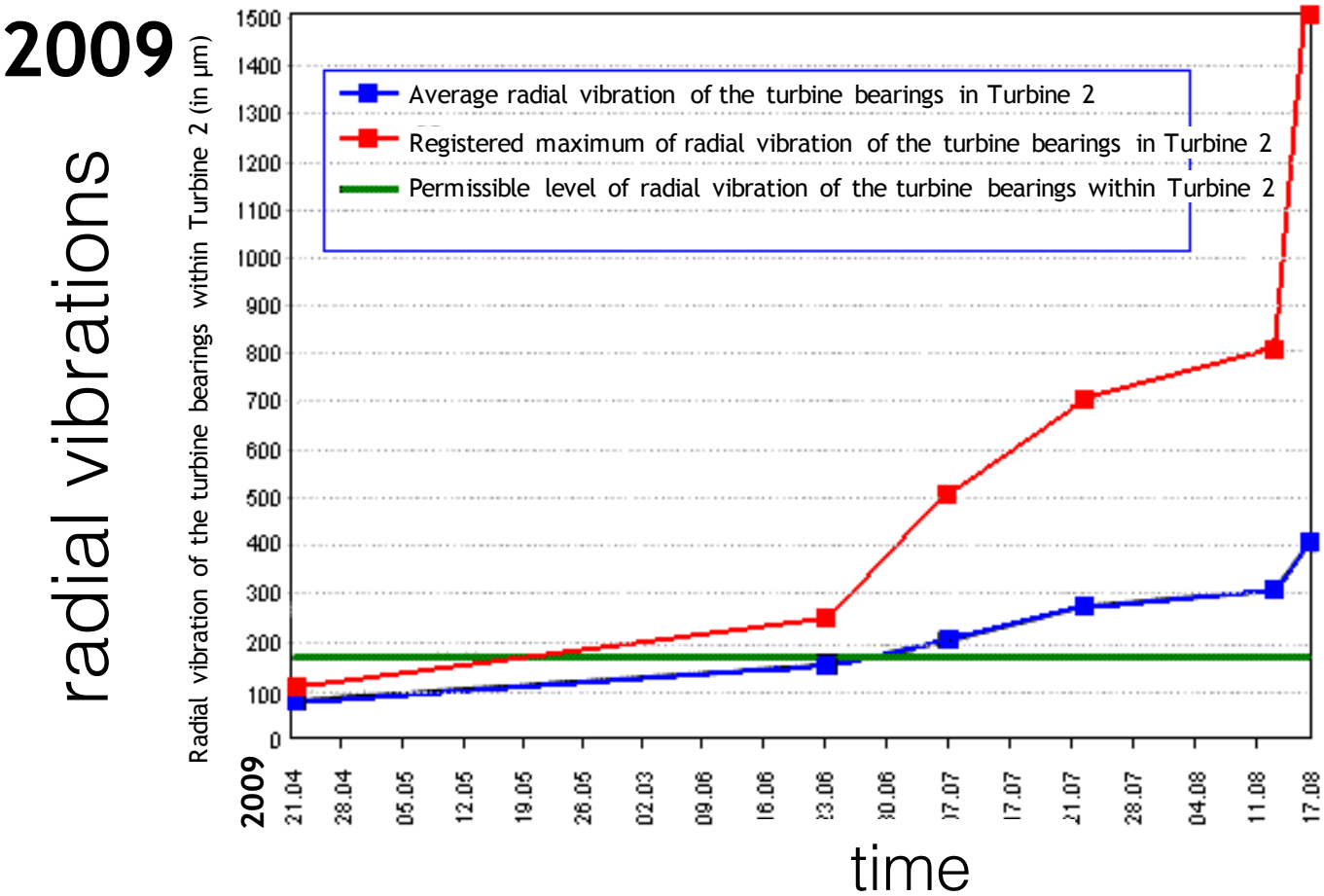
EXAMPLES:
Sayano-Shushenskaya hydropower station (2009)



- RusHydro – the largest power-generating company in Russia, and the third largest hydroelectric power producer in the world with 53 hydropower stations under its supervision.

(D. Chernov and D. Sornette, 2016)

EXAMPLES:
Sayano-Shushenskaya hydropower station (2009)



RusHydro senior management

No warning given
about abnormal vibrations in Turbine 2

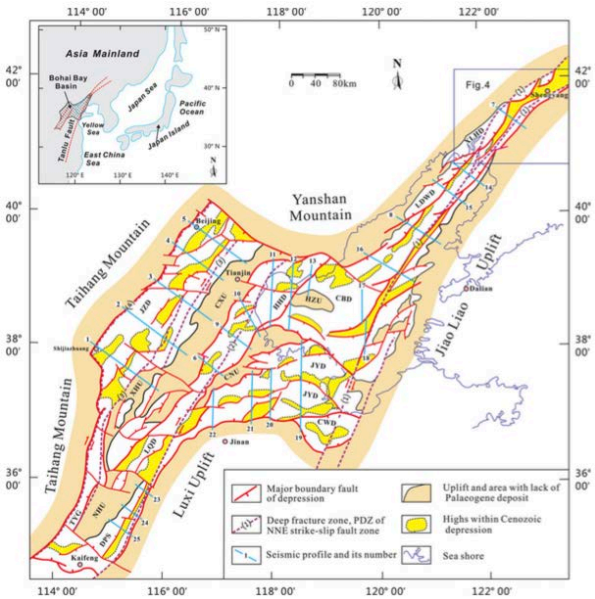
Station management

RusHydro security service

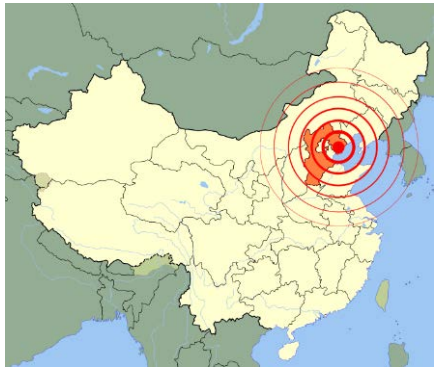
- SSHPS management gave no warning to RusHydro headquarters about abnormal vibrations in Turbine 2, even though these vibrations were known to them for several months leading up to the accident.

(D. Chernov and D. Sornette, 2016)

Similar power-law acceleration of precursor anomalies observed in Tangshan and Haicheng

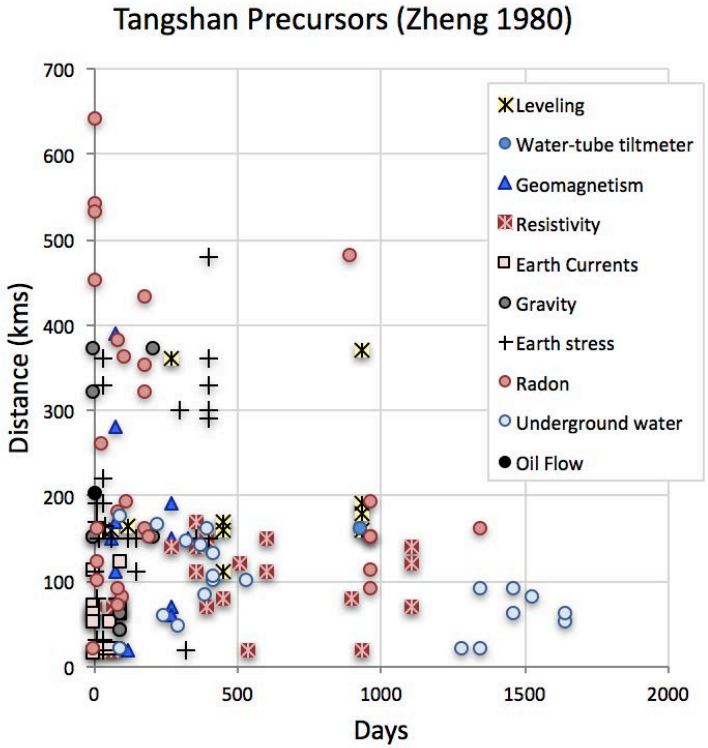


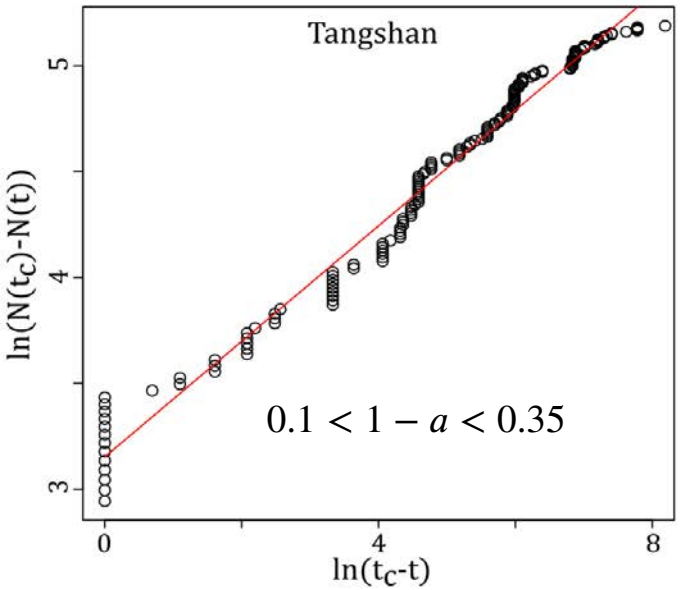
1976 Tangshan earthquake (M=7.6)

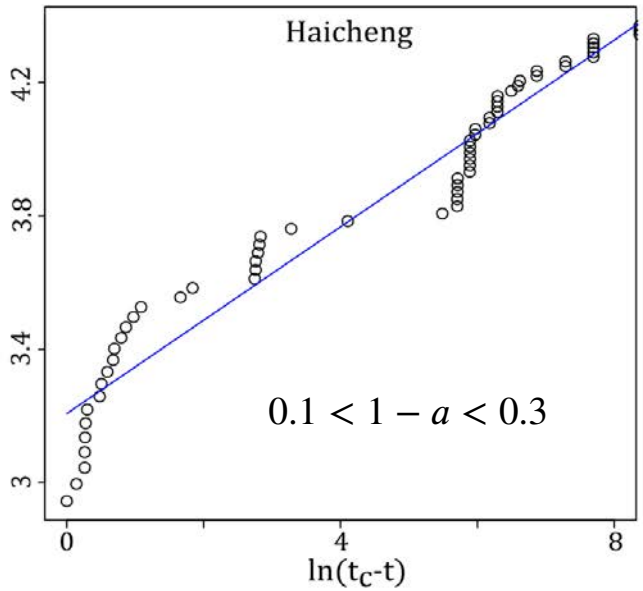


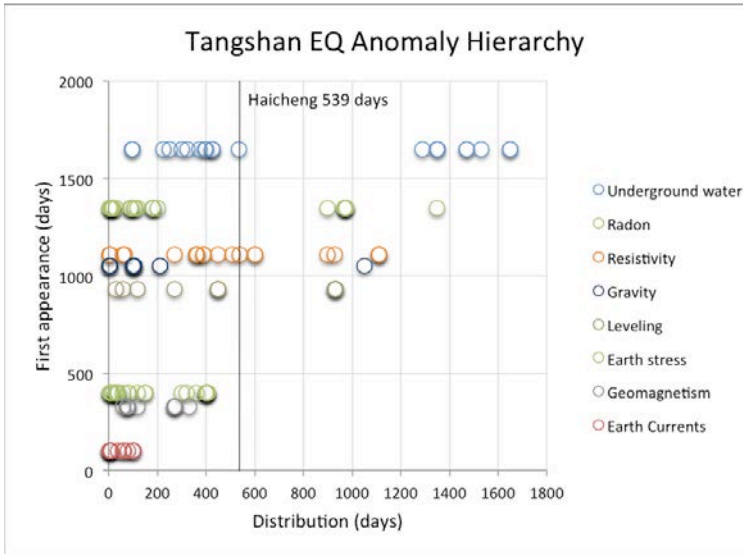
$$N(t_c) - N(t) = c(t_c - t)^{1-a}$$

1975 Haicheng earthquake (M=7.5)





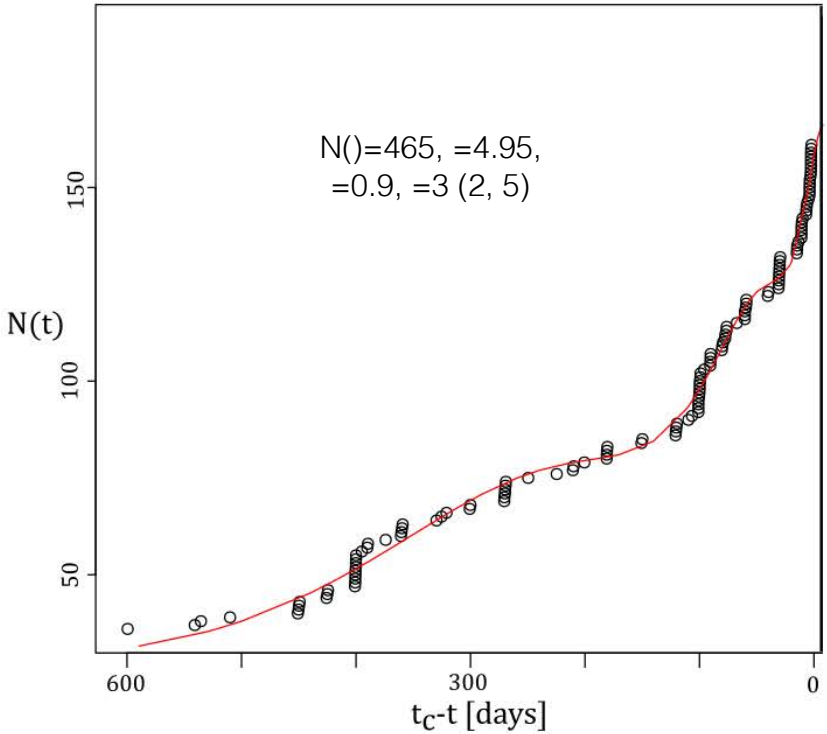


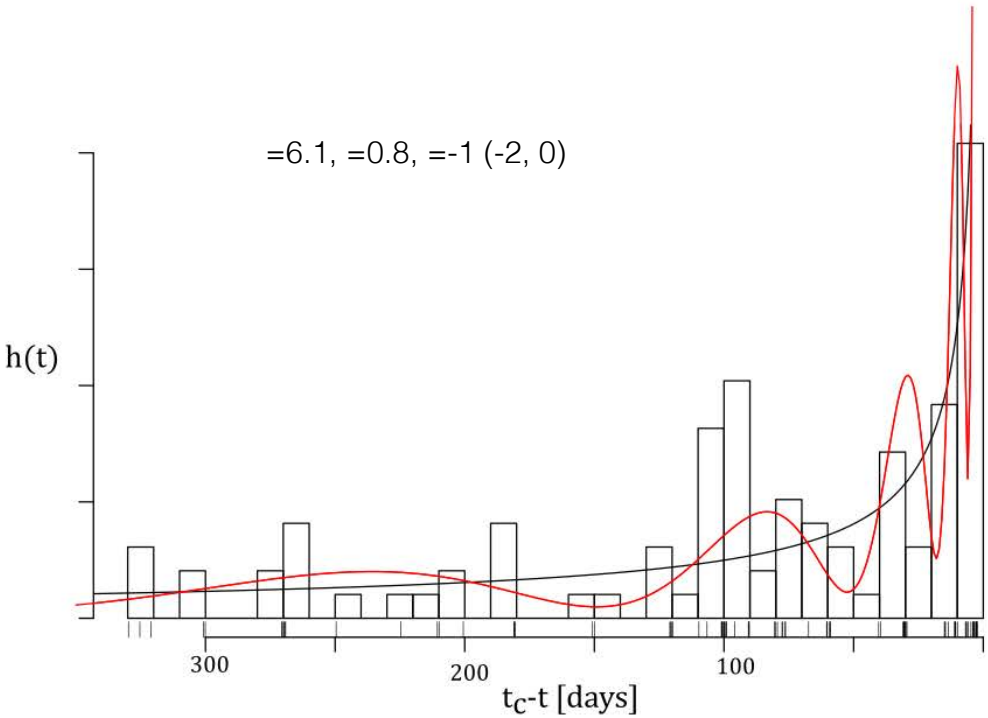


Scatterplot of log of variables, and fitted linear regression. Similar slopes, and hence hazard rate exponents, are inferred.

Was the Tangshan earthquake predictable?

$$N(t) = b + c\left(t_c - t\right)^{1-a}\left(1 + d\,cos\left(\omega \ln(t_c - t)\right) + \phi\right) \quad , \; 0<<1$$





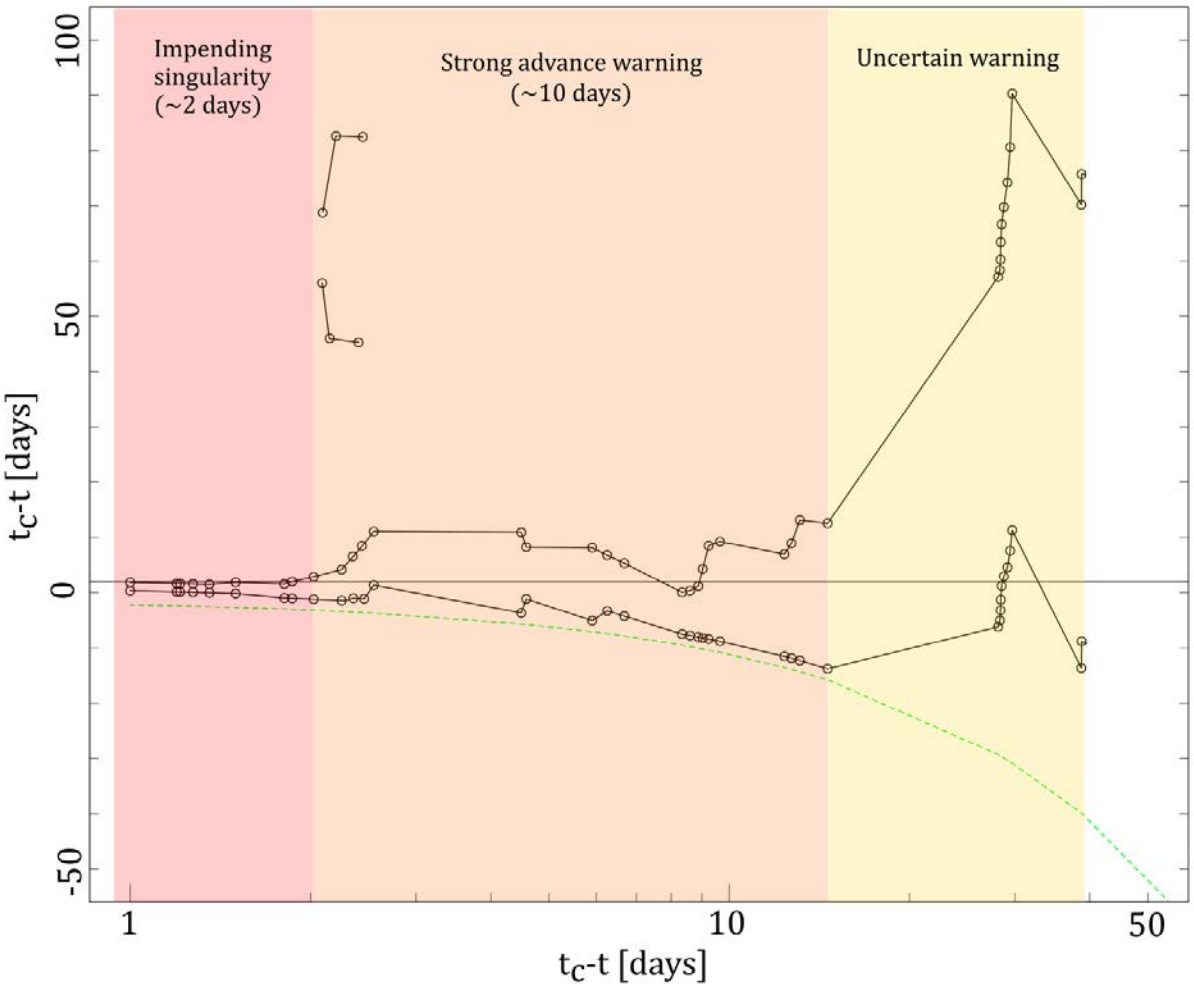
Left: Cumulative sum of anomalies, starting 600 days prior to the Tangshan earthquake. The LPPL fitted by regression is plotted, with key parameters given above, including the 95% CI for the critical time. Right: Histogram of anomalies, starting 1 year before Tangshan, along with pure PL (black) LPPL (red), fitted by density estimation.

For the Tangshan earthquake (1976, M=7.6) a strong LPPL signature is detected

- LPPL model cannot be rejected when compared with flexible nonparametric models
- Significant log-periodic corrections to the power law are detected
  - The loglikelihood of the LPPL consistently >10 points greater than the pure PL.
- Confirmed for regression and density-based estimates, for a range of left-truncations of the sample.

LPPLS provides a strong early warning signal!

(LPPLS: log-periodic power law singularity)



95% profile likelihood confidence interval of LPPLS model fit on a data window with a rolling right truncation point – ranging from about 1 month to 1 day before the Tangshan earthquake. The time remaining to the earthquake (horizontal axis) is plotted in log scale. The green dashed line is the "y=x" line. Note: bimodal objective function results in two intervals for a brief period.

<u>Tangshan earthquake prediction experiment</u>

Method: "backtest" / immitate real-time

- Fit the LPPLS starting 50 days before the earthquake, and compute 95% confidence interval for critical time.
- Update prediction in "real time" with each new observed anomaly.

Result:

- > 1 month before: incoherent signature
- 1 month before: uncertain warning
- 1 week before: convergent alarm
- 1 day before: absolute alarm

Failure of management

- lack of courage and laziness to address the real problems (status quo, lack of right incentives)

- lack of understanding of the nature of complex systems

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  "Nature is more imaginative than the best manager, engineer or mathematician!"

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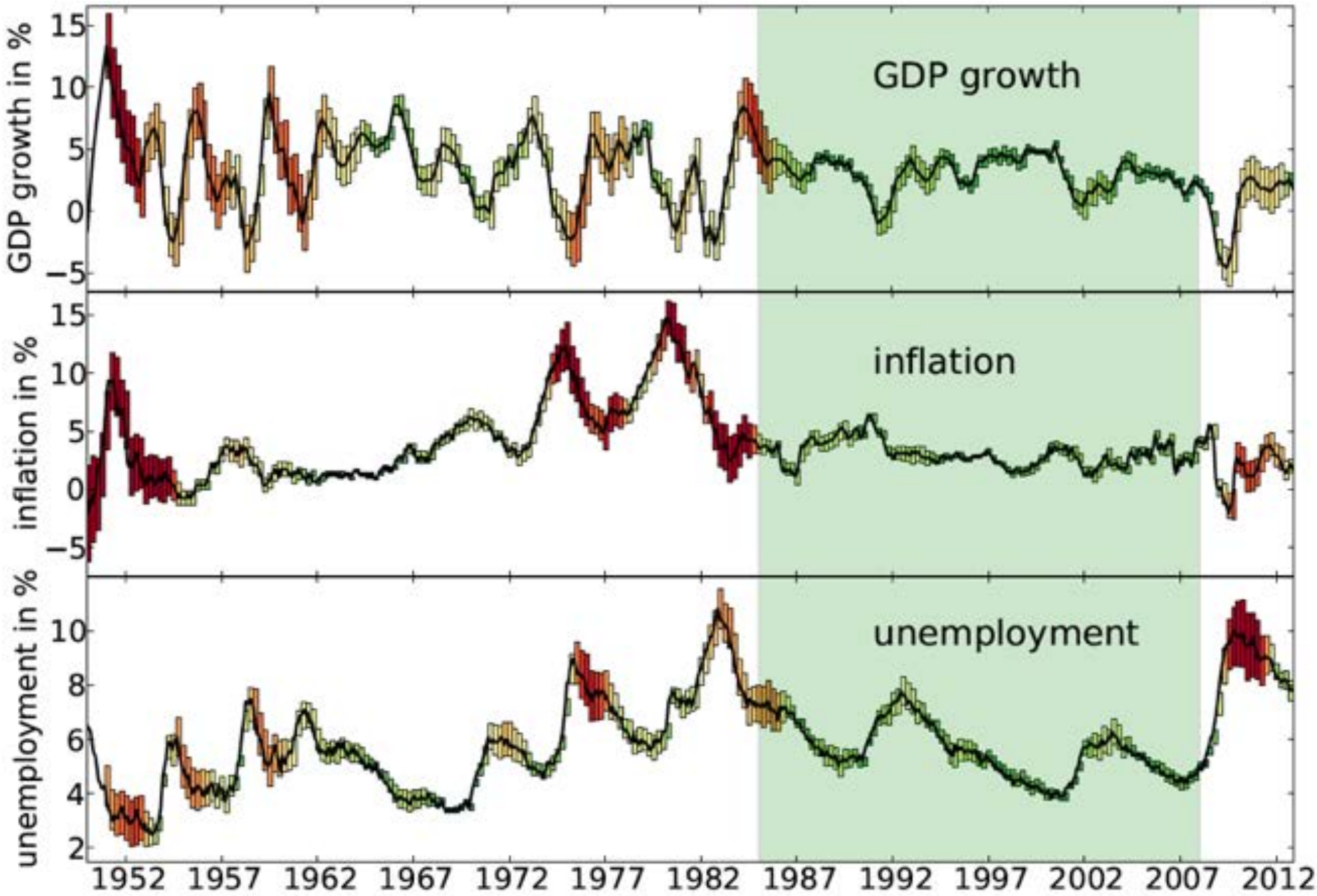
FINANCIAL CRISIS 2008

MISLEADING METRICS: THE GREAT MODERATION

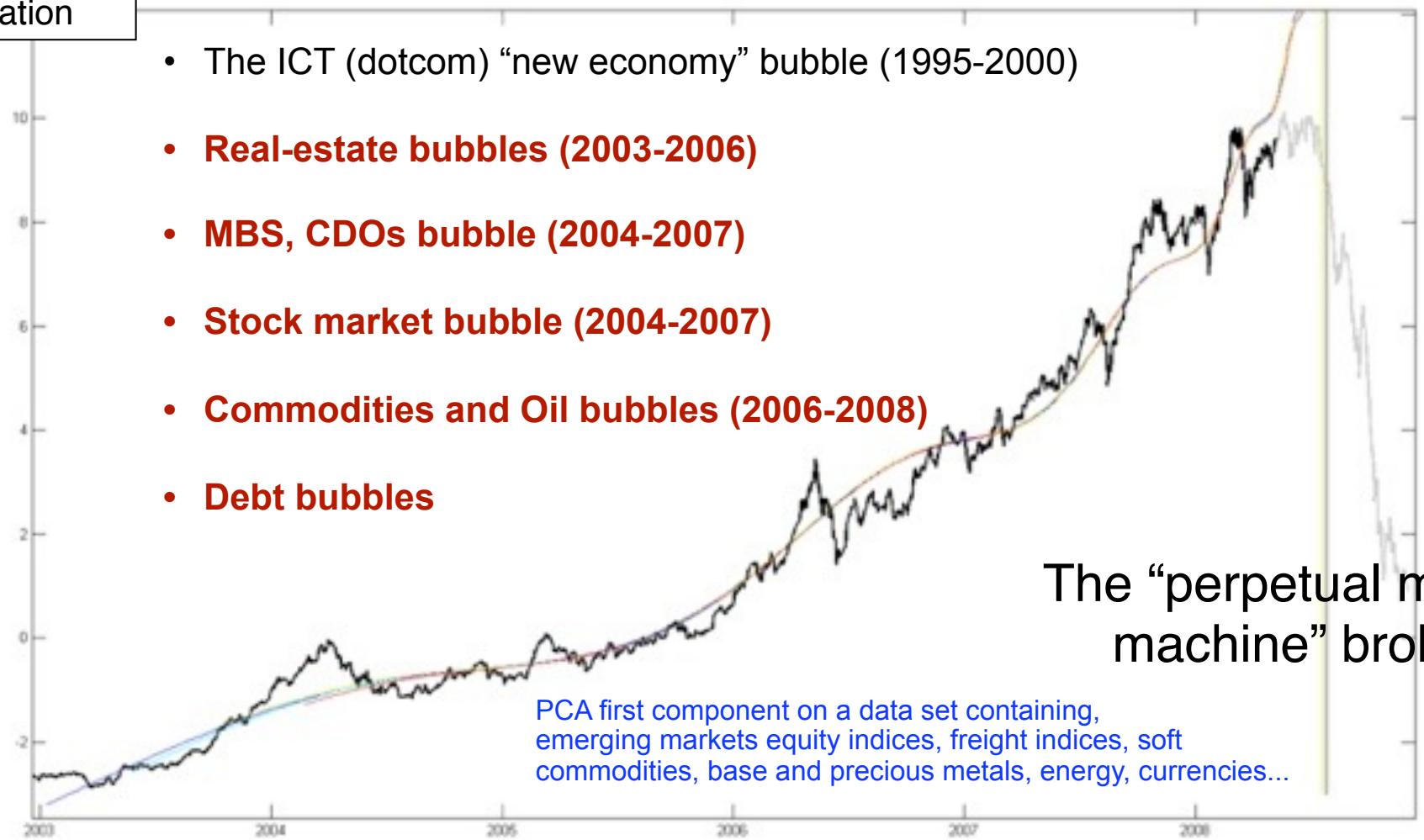


source: U.S. Bureau of Labor Statistics and Zalan Forro (ETH Zurich).

The Global Bubble (2003-2008) and the illusion of the perpetual money machine (1980-2008)

Index of over-valuation

- Worldwide bubble (1980-Oct. 1987)
- The ICT (dotcom) “new economy” bubble (1995-2000)
- **Real-estate bubbles (2003-2006)**
- **MBS, CDOs bubble (2004-2007)**
- **Stock market bubble (2004-2007)**
- **Commodities and Oil bubbles (2006-2008)**
- **Debt bubbles**



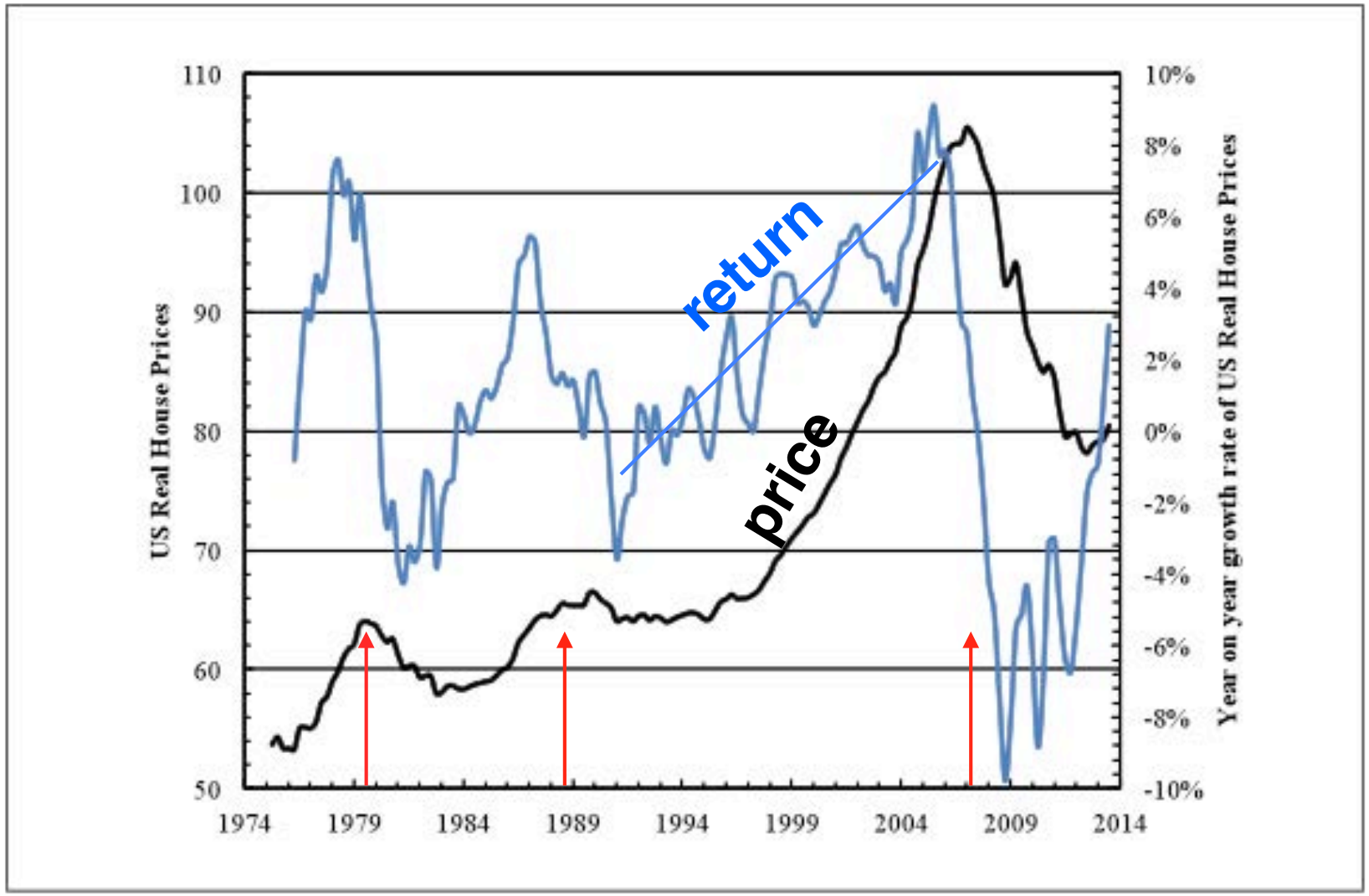
The “perpetual money machine” broke.

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

2003 2004 2005 2006 2007 2008 2009

D. Sornette and P. Cauwels, 1980-2008: The Illusion of the Perpetual Money Machine and what it bodes for the future, Risks 2, 103-131 (2014) (http://arxiv.org/abs/1212.2833)

U.S. real-estate bubble

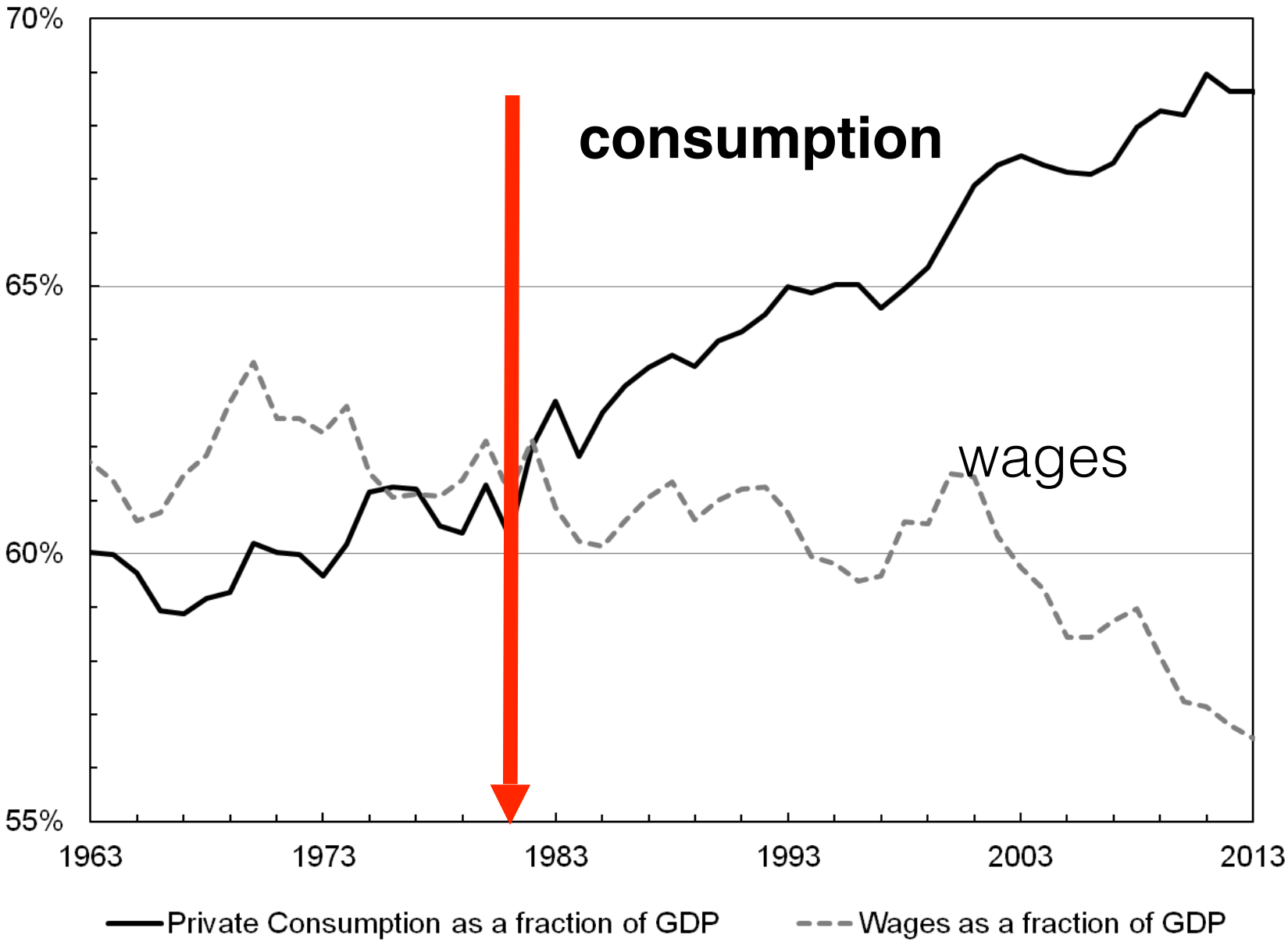


Real U.S. House Prices between 1974 and 2014. Levels are shown in black and should be read on the left axis. Yearly growth rates are shown in blue and should be read on the right axis. Three peaks in the growth rate coincide with a correction in the levels. When the growth itself grows, the process becomes unstable and a correction follows (Source: Federal Reserve Bank of Dallas international house price dataset, http://www.dallasfed.org/institute/houseprice/)

W.-X. Zhou and D. Sornette, Is There a Real-Estate Bubble in the US? Physica A 361, 297-308 (2006) (http://arxiv.org/abs/physics/0506027)

The illusion of the "PERPETUAL MONEY MACHINE"

The share of wages and of private consumption as a percentage of the Gross Domestic Product (GDP) for the U.S. from 1963 until 2013. Source of data: Ameco, the Annual Macro-Economic Database of the European Commission, and Michel Husson.



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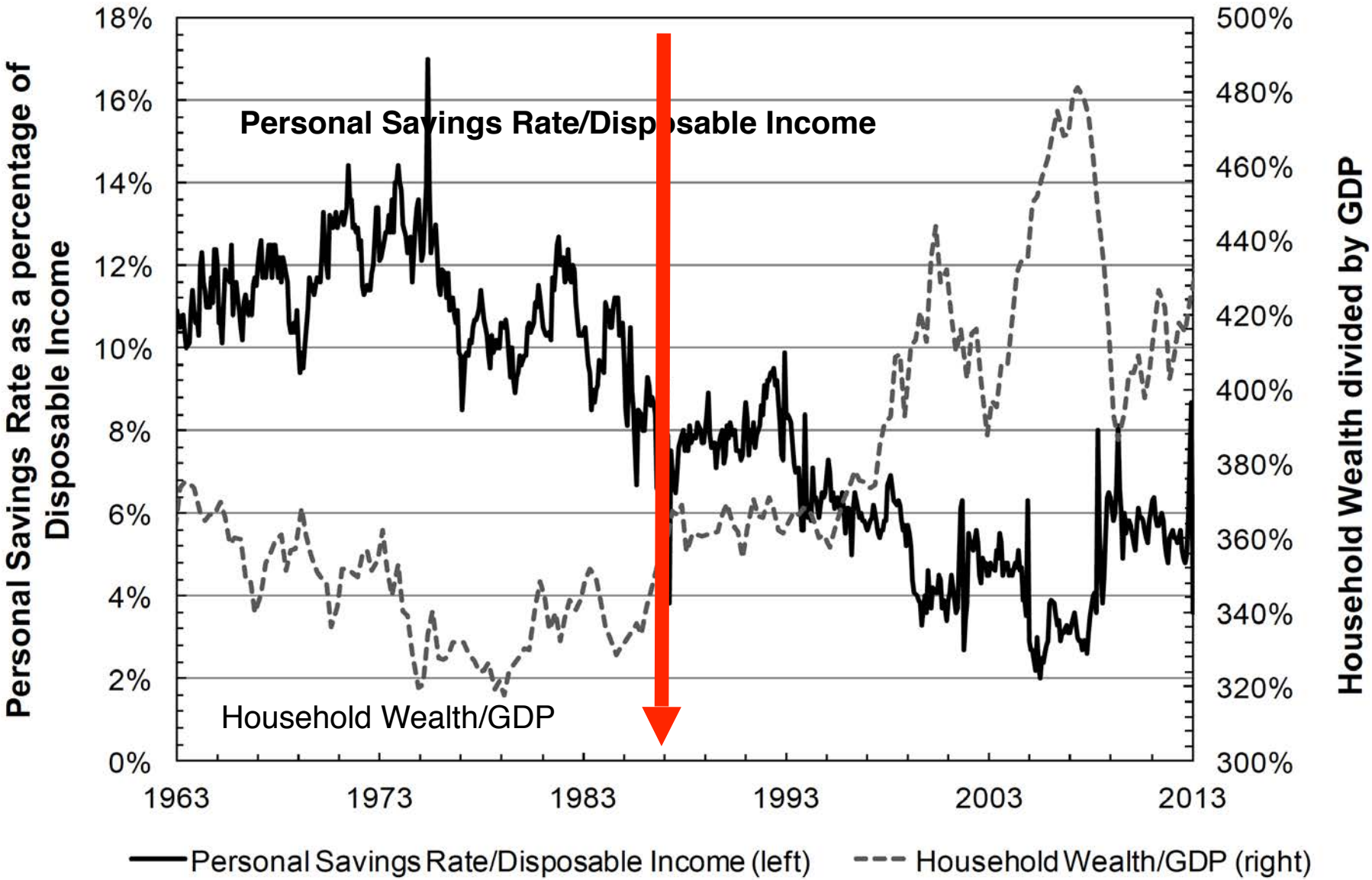


Change from productivity-based growth to virtual-based growth around 1980

-direct evidence on productivity

-stock markets

-financialisation

-debt

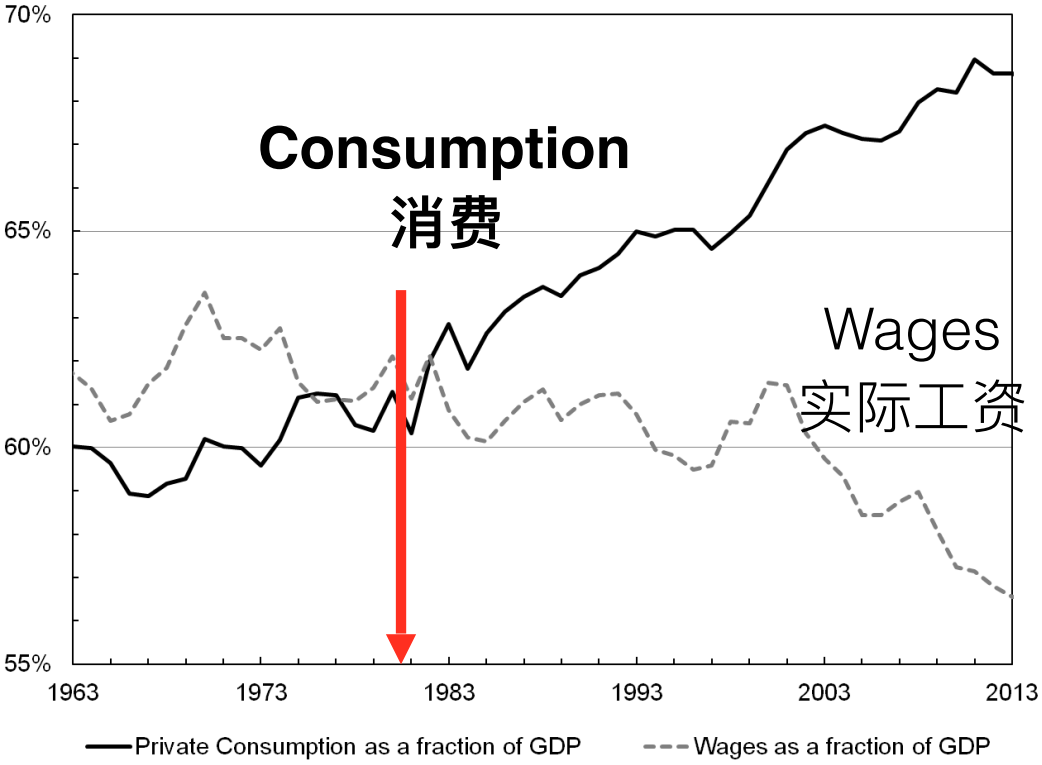
all change around 1980 !

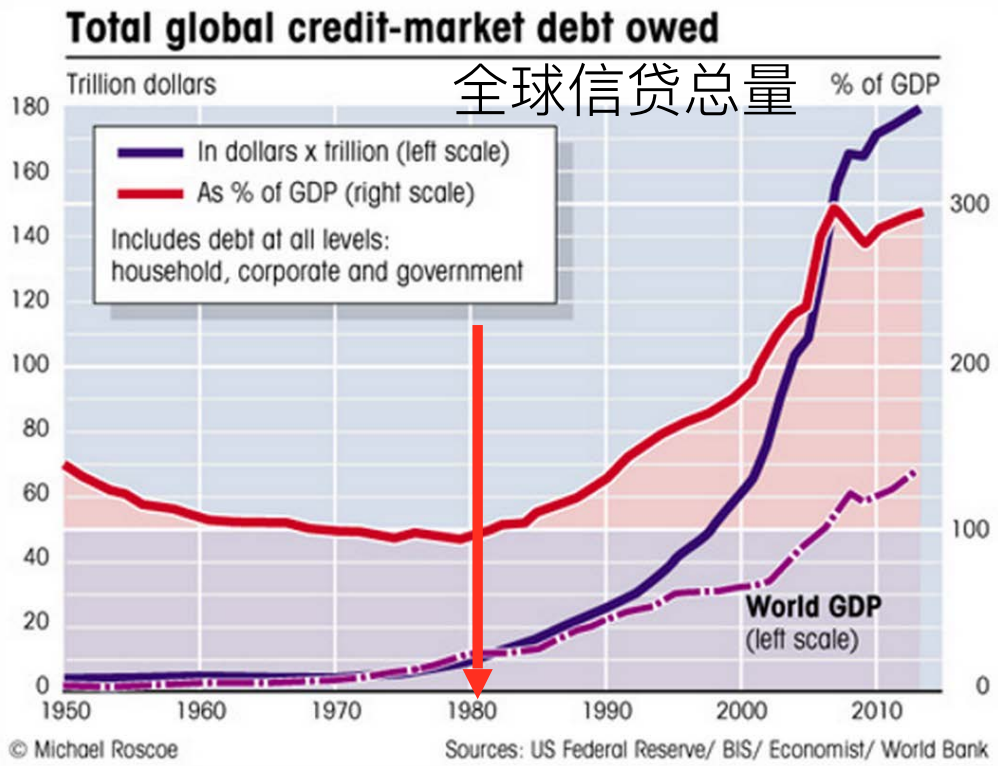
-monetary policies

-government and fiscal policies

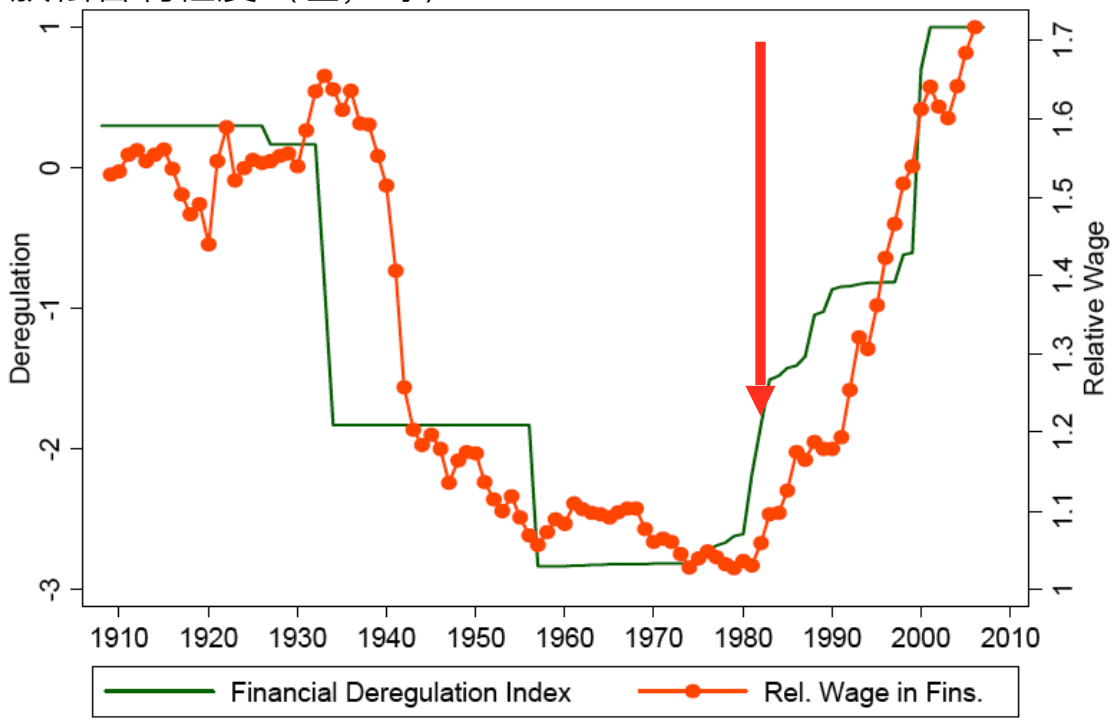
-inequality

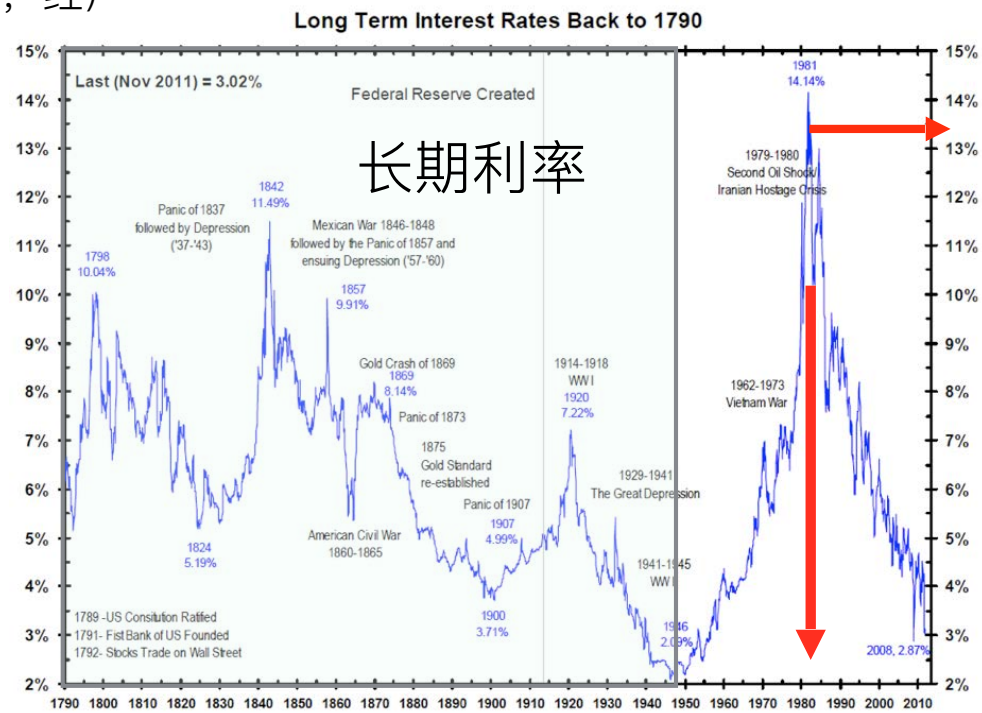
(D. Sornette, 2017)





放松管制程度（左，绿）　　金融行业相对工资（右，红）





Methodology for diagnosing bubbles

The Log-Periodic Power Law (LPPL) model

- Positive feedbacks of higher return anticipation
  - Super exponential price
  - Power law "Finite-time singularity"
- Positive feedback of negative spirals of crash expectation
  - Accelerating large-scale financial volatility
  - Log-periodic discrete scale-invariant patterns

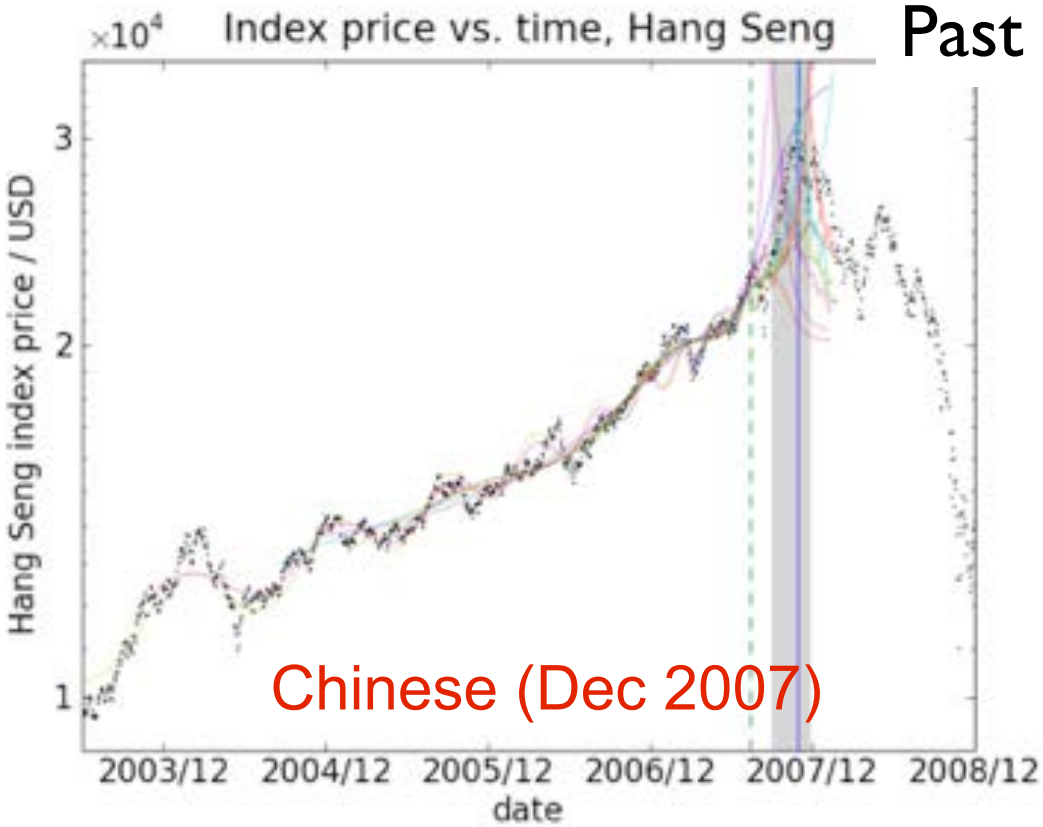
Expectation component of the price dynamics:

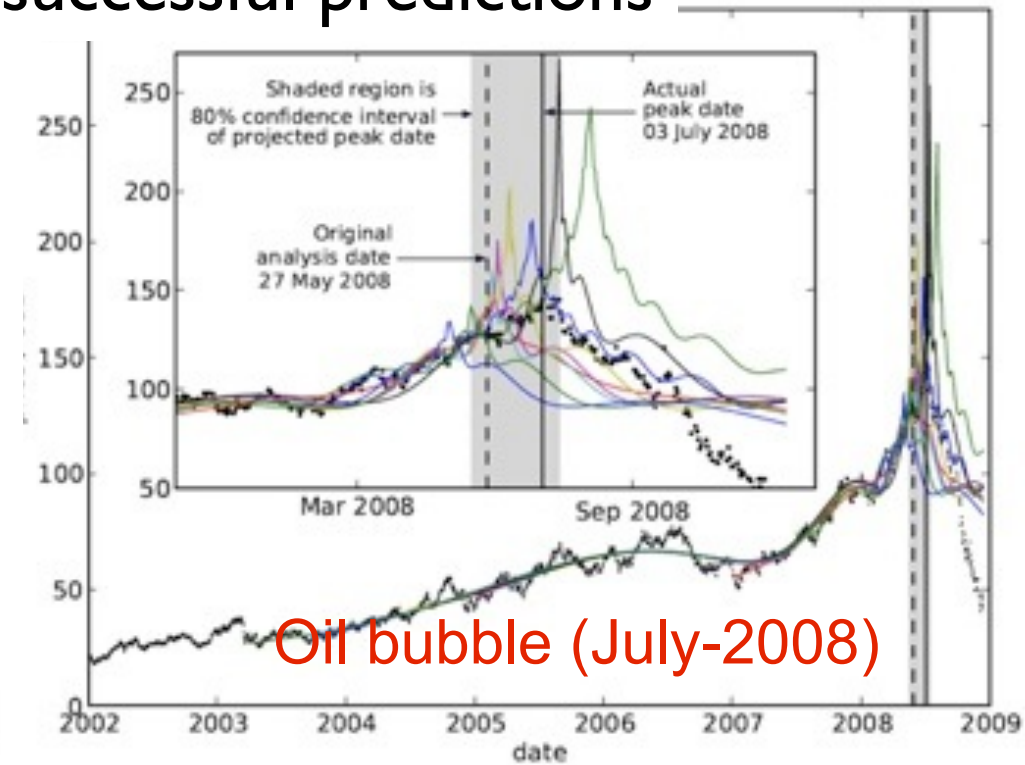
$$\ln(P) = \overset{1}{\boxed{A + B\,(t_c - t)^m}} + \overset{2}{\boxed{C\,(t_c - t)^m}} \cos\left(\overset{3}{\boxed{\omega \ln[t_c - t]}} - \phi\right)$$

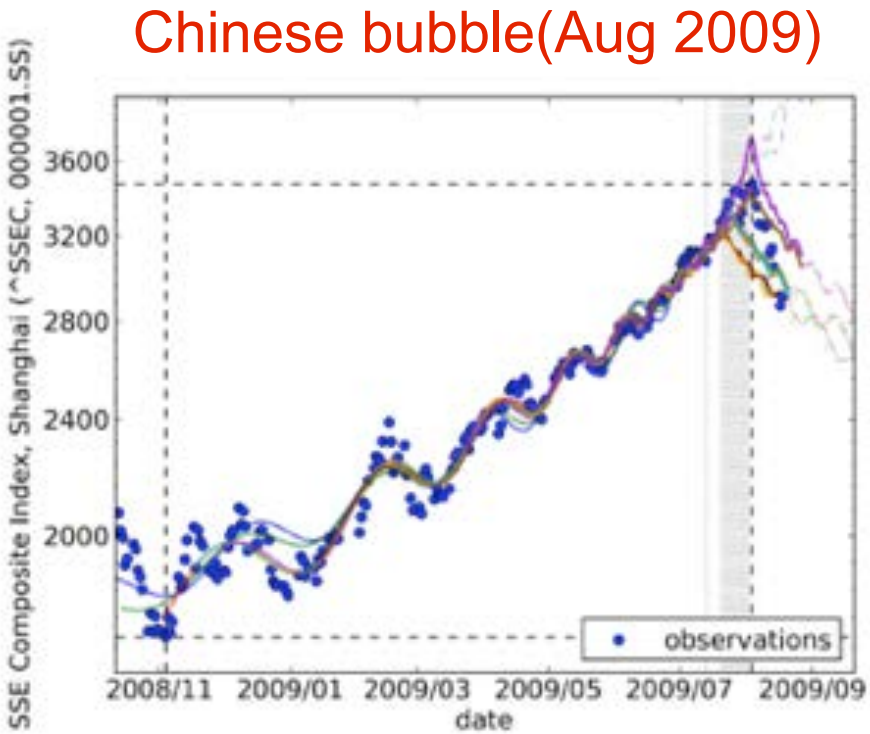
A. Johansen, D. Sornette and O. Ledoit
Predicting Financial Crashes using discrete scale invariance,
Journal of Risk, vol. 1, number 4, 5-32 (1999)

A. Johansen, O. Ledoit and D. Sornette, Crashes as critical points,
International Journal of Theoretical and Applied Finance Vol. 3, No. 2
219-255 (2000)

Past successful predictions







Ex-ante forecast of silver bubble

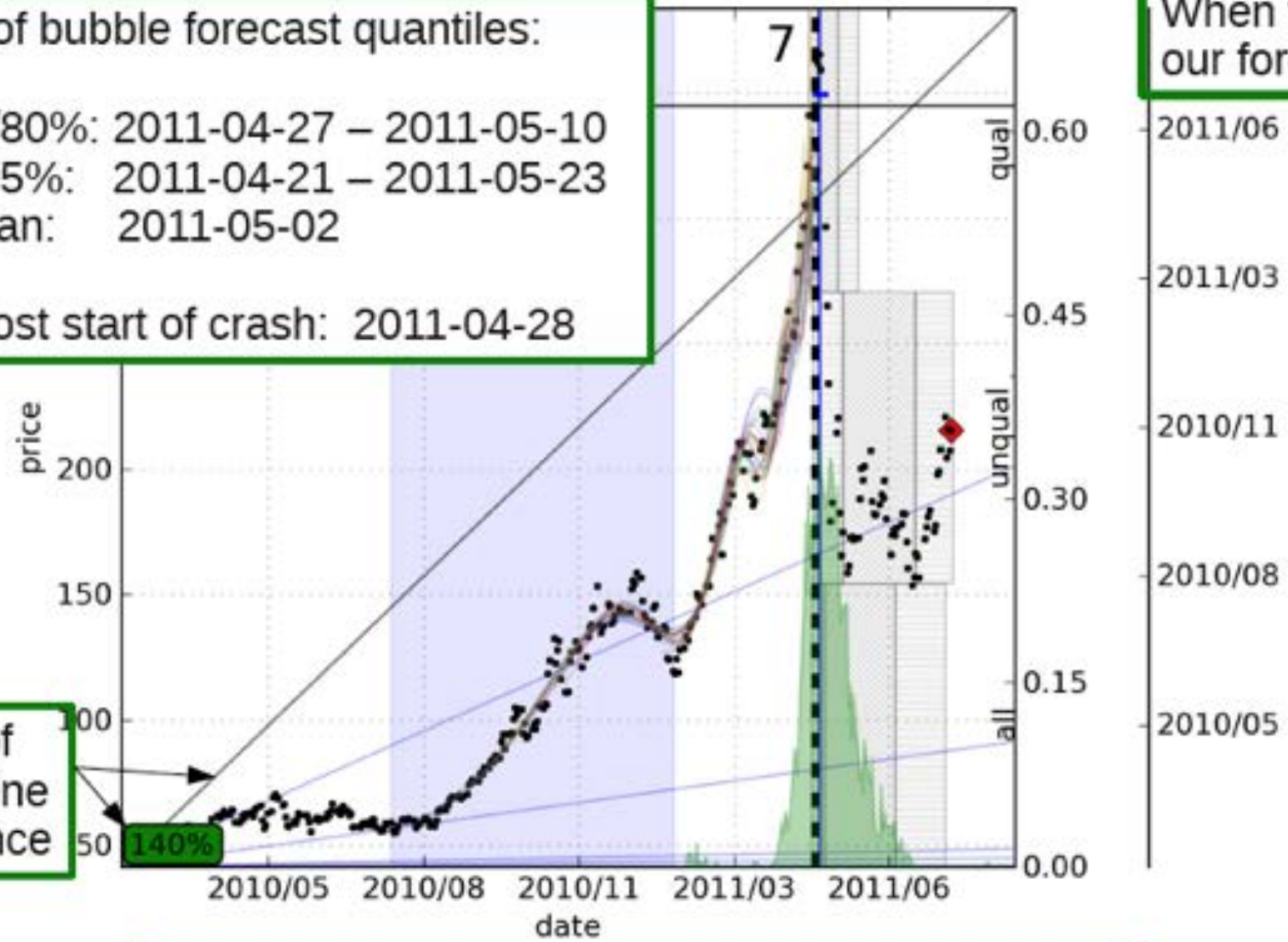
Proshares Ultra Silver | AGQ | t2 = 2011-04-25

When we made our forecast

End of bubble forecast quantiles:

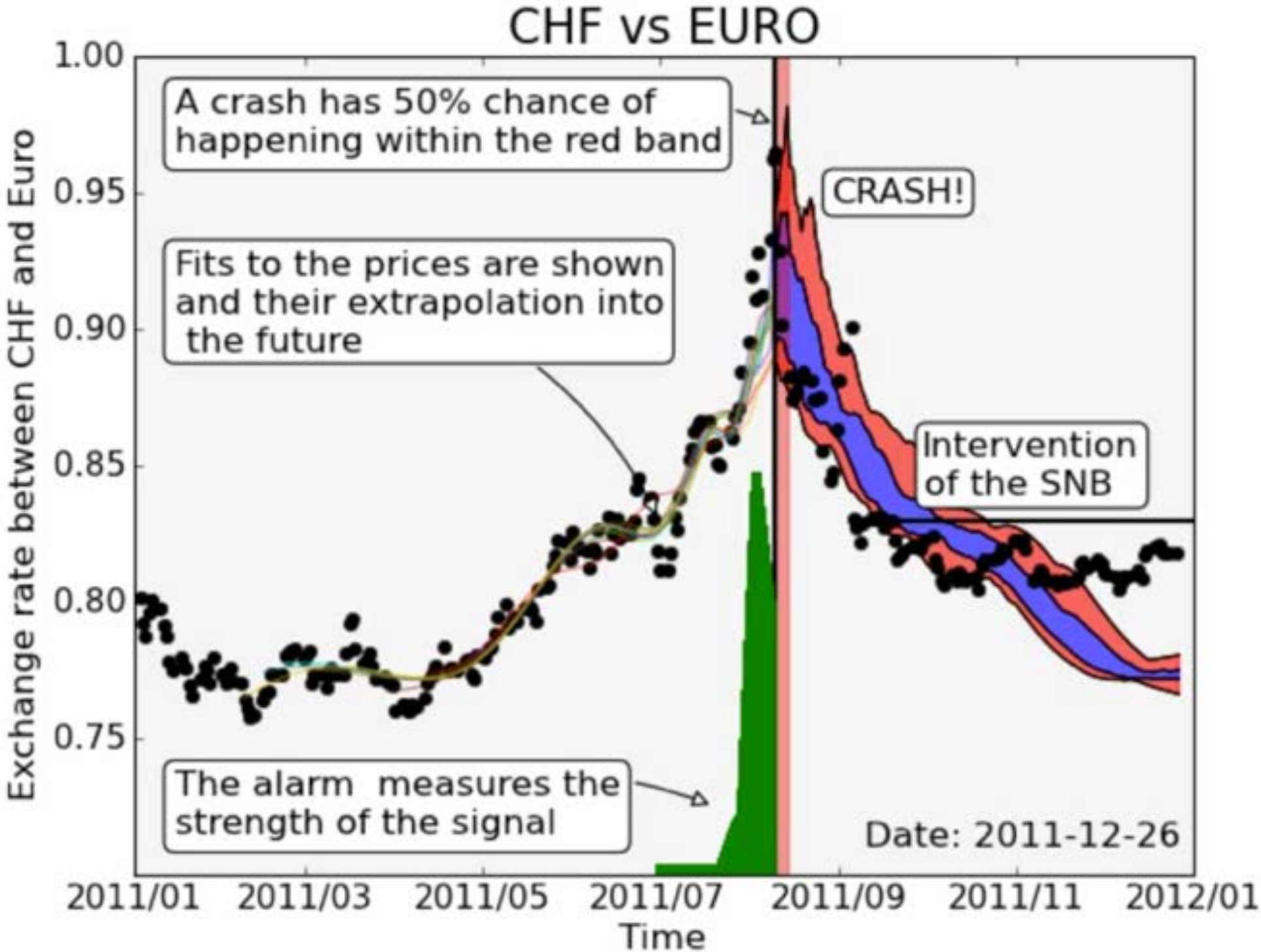
20%/80%: 2011-04-27 – 2011-05-10
5%/95%: 2011-04-21 – 2011-05-23
Median: 2011-05-02

Ex-post start of crash: 2011-04-28



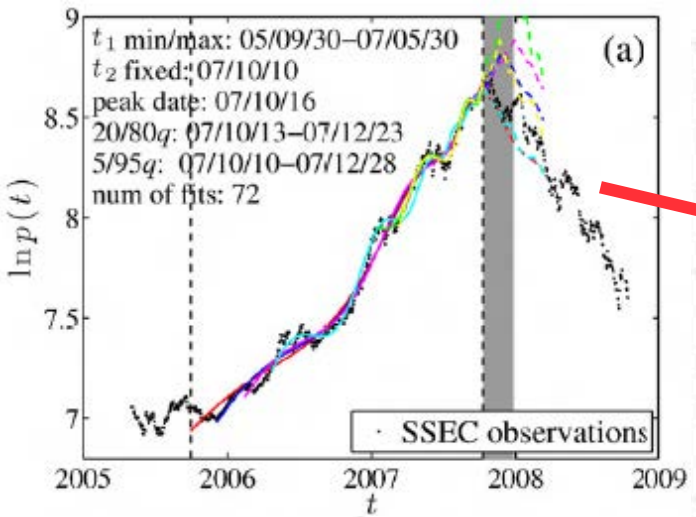
"Return" of diagonal line for reference

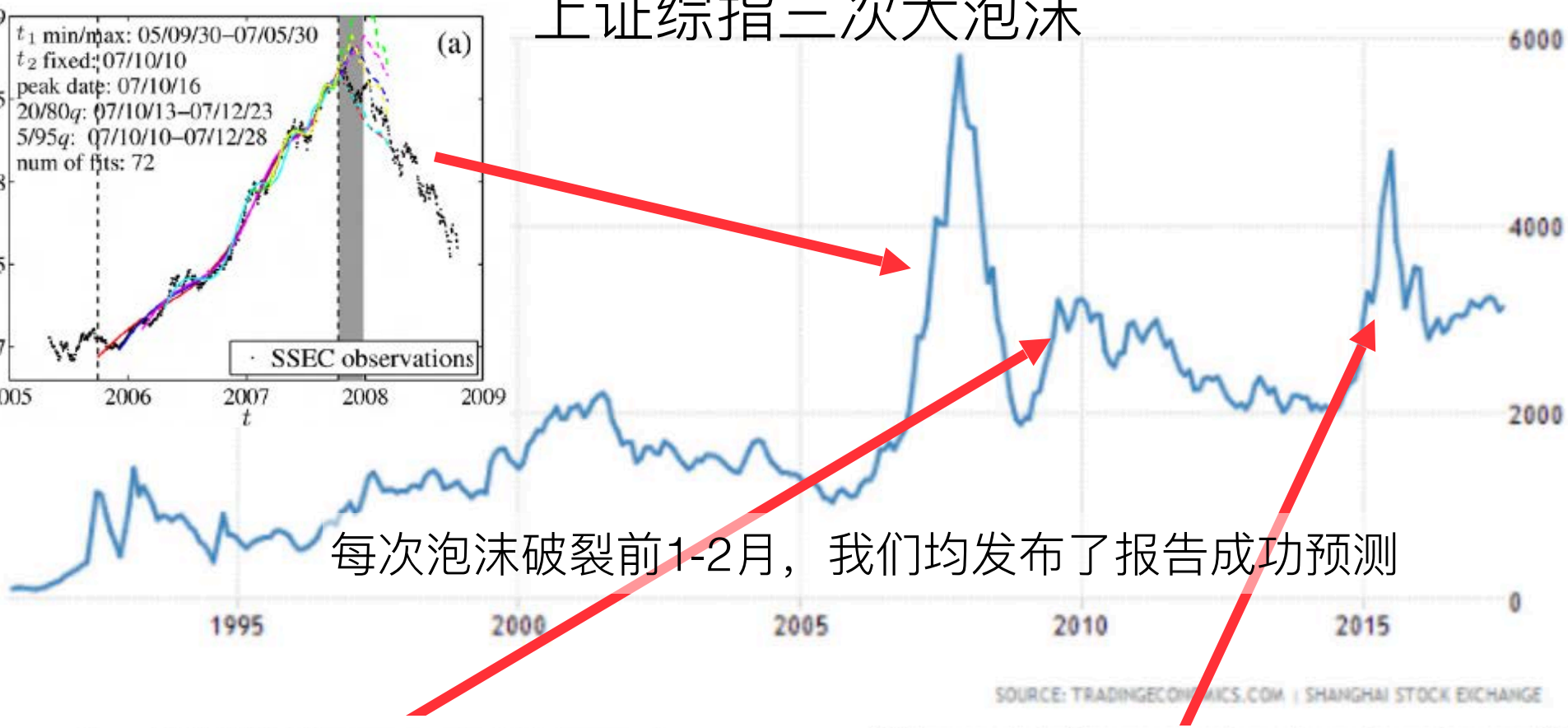
We successfully traded on the growth and crash.


CHF vs EURO
A crash has 50% chance of happening within the red band
CRASH!
Fits to the prices are shown and their extrapolation into the future
Intervention of the SNB
The alarm measures the strength of the signal
Date: 2011-12-26
Exchange rate between CHF and Euro
1.00
0.95
0.90
0.85
0.80
0.75
2011/01
2011/03
2011/05
2011/07
2011/09
2011/11
2012/01
Time

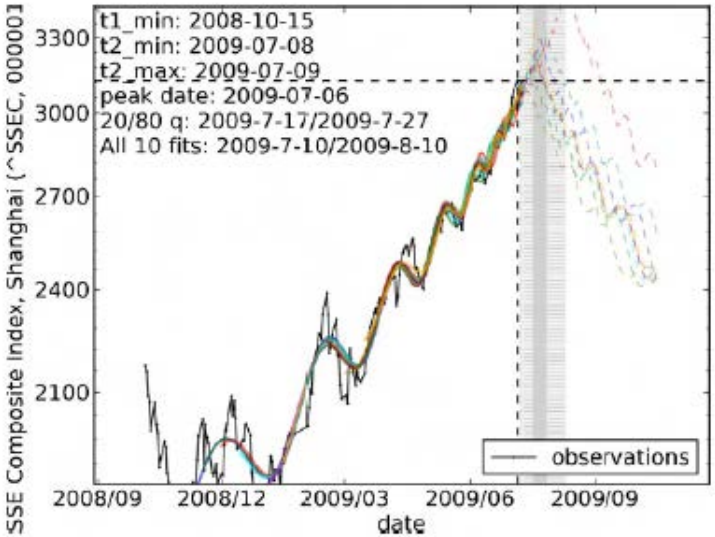
Shanghai Composite Index since 1990

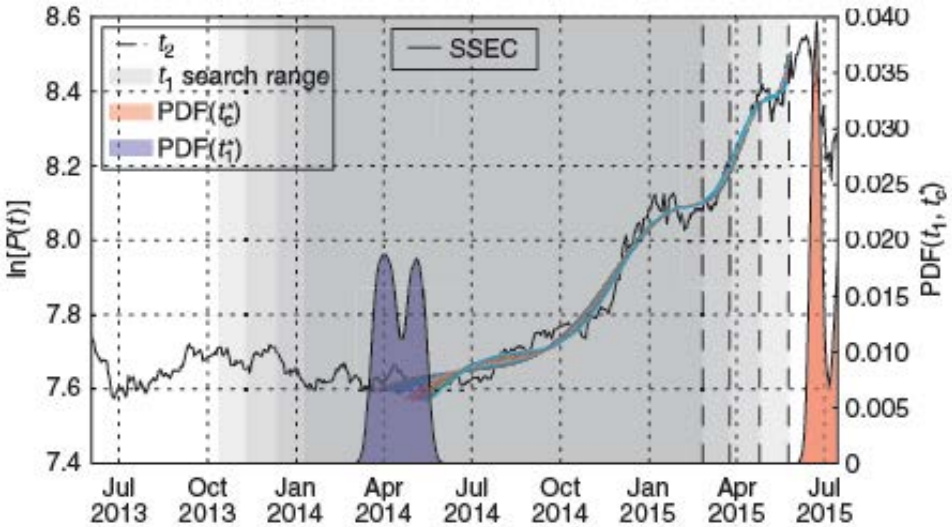
上证综指三次大泡沫





每次泡沫破裂前1-2月，我们均发布了报告成功预测





Failure of management

- lack of courage and laziness to address the real problems (status quo, lack of right incentives)

- lack of understanding of the nature of complex systems

- **lack of imagination to explore the relevant possible scenarios**

  "Nature is more imaginative than the best manager, engineer or mathematician!"

- lack of leadership to foster information transfer and communication, for communicating the vision, goals and targets

- The fair reward problem: misguided incentives to reward success instead of process ("luck vs skill")

Case studies of 45 past disasters in all industry sectors

- The findings challenge the axiom of management theory that states that managers oversee people by means of information.
- In many cases, the risk-information and communication is distorted, thereby affecting the management decisions and an organization's response.

Dmitry Chernov & Didier Sornette

Man-made Catastrophes and Risk Information Concealment

Case Studies of Major Disasters and Human Fallibility

2016

Man-made crisis and risk-information deficit

INDUSTRIAL SECTOR

- Vajont Dam disaster
- Val di Stava dam disaster
- Bhopal disaster – the largest chemical leak in history by death tool
- Three Mile Island nuclear accident – third largest nuclear accident in history
- Challenger Shuttle disaster
- Chernobyl disaster – the largest nuclear accident in history
- Exxon Valdez oil spill
- Ufa train disaster
- Piper Alpha oil platform explosion
- Deepwater Horizon oil spill – the largest marine oil spill in history
- Sayano-Shushenskaya hydropower station accident
- Raspadskaya coal mine burnout
- Fukushima-Daiichi nuclear disaster – second largest nuclear accident in history
- Minamata mercury poisoning
- Worldwide asbestos crisis
- Savar building collapse
- Shale energy production
- Boeing 787 Dreamliner lithium-ion batteries
- Sukhoi Superjet crash

FINANCIAL SECTOR

- Barings Bank collapse
- Enron bankruptcy
- Worldcom accounting scandal
- Dynegy, Reliant Energy and El Paso accounting fraud
- Subprime mortgage crisis
- Lehman Brothers collapse – the largest bankruptcy in history
- World derivatives market
- J.Kerviel / Societe Generale trading loss
- K. Adoboli /UBS trading loss
- Californian electricity crisis
- Tyco and Healthsouth corporate fraud
- Parmalat market rigging
- Real debt and liabilities of US government

RETAIL PRODUCTION

- Toyota pedal crisis
- Poly Implant Prothese fraud
- Global tobacco industry
- Ford-Firestone tire controversy
- Intel Pentium FDIV bug crisis
- Cadbury Schweppes salmonella recall
- Chinese milk scandals
- Apple iPhone 4 antenna
- Mad cow disease
- GM recall

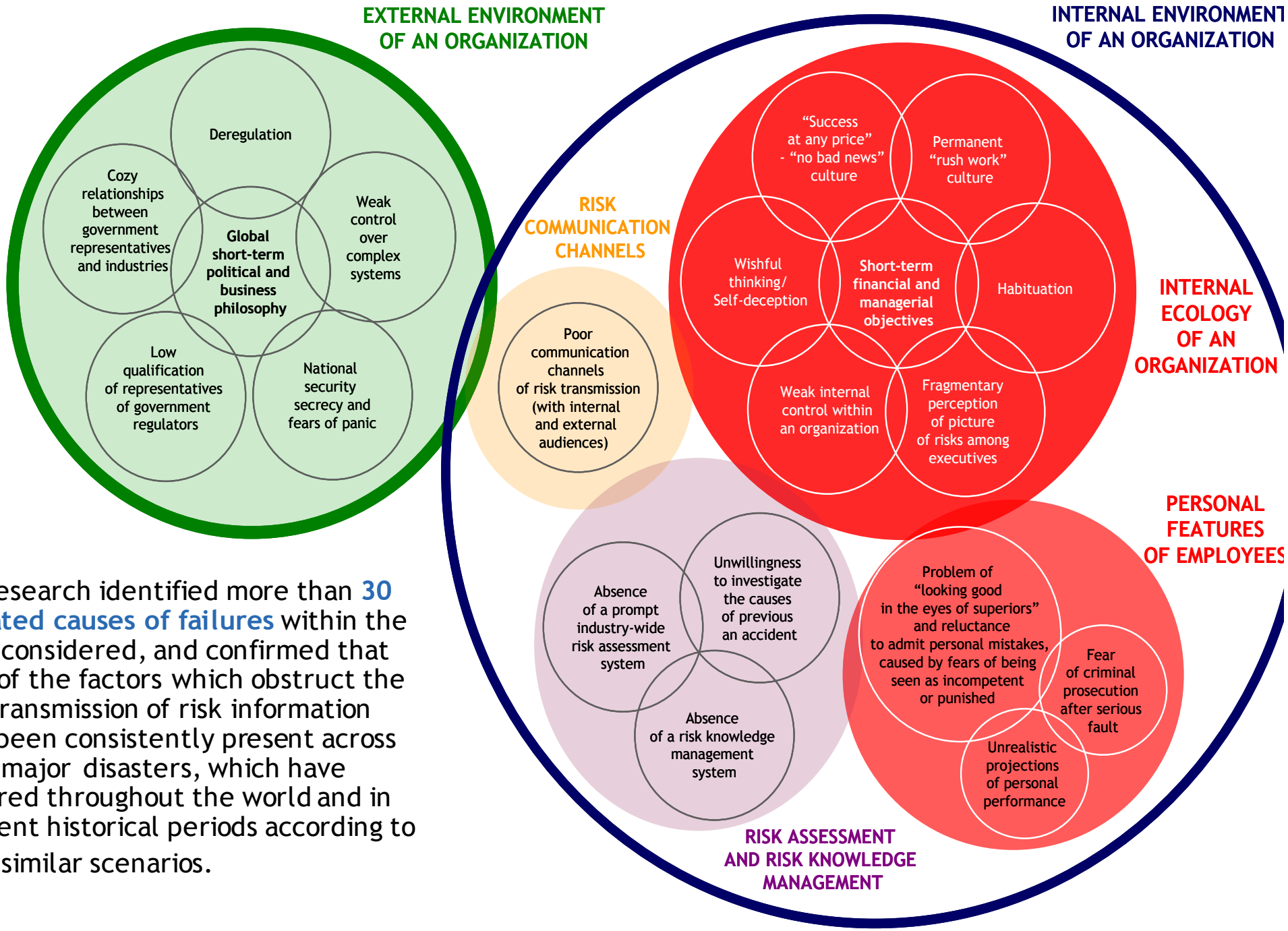
AGRICULTURE

- Genetically modified organisms

NATIONAL SECURITY AND NATURAL DISASTERS

- Worldwide Spanish flu outbreak
- SARS outbreak
- Unreadiness of USSR for the Nazi invasion
- Kursk submarine accident
- Hurricane Katrina disaster
- Global cyber arms race
- Concealment of vulnerabilities in software
- Krymsk flooding
- Massive wildfires in European part of Russia

MAIN RESULTS OF THE RESEARCH



- The research identified more than **30 repeated causes of failures** within the cases considered, and confirmed that most of the factors which obstruct the free transmission of risk information have been consistently present across many major disasters, which have occurred throughout the world and in different historical periods according to quite similar scenarios.

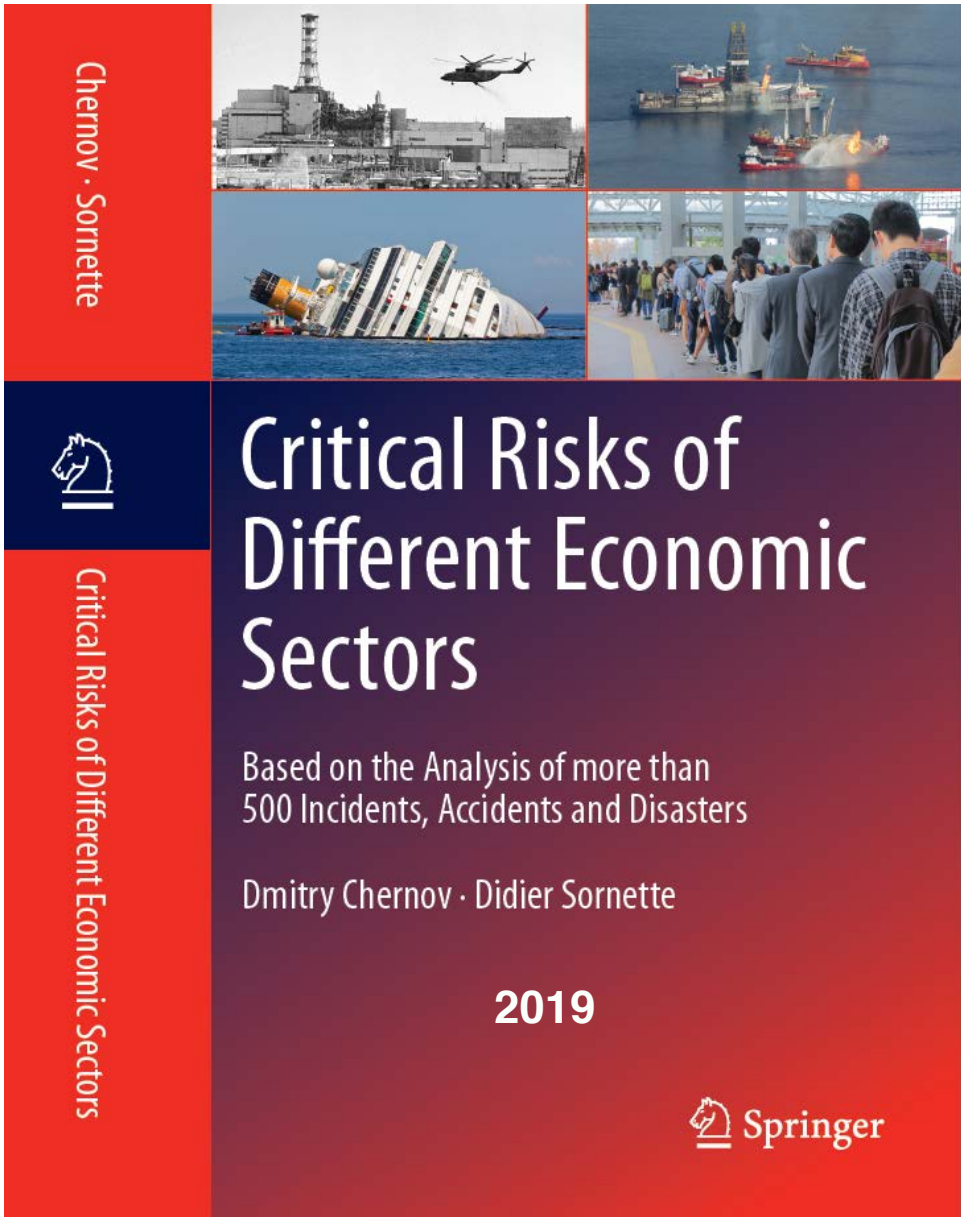
- Major differences between the kinds of risk encountered in different sectors of industry - production (including agriculture) and services

- identifies the main features of accidents within different industries.

- Because of these differences, unique risk-mitigation measures will need to be implemented in one industry that cannot be implemented in another, leading to large managerial differences between these broad economic sectors.

- Based on the analysis of more than 500 disasters, accidents and incidents – around 230 cases from the production sector and around 280 cases from the service sector

- compare the risk response actions appropriate within different sectors, and establish when and how it is possible to generalize the experience of dealing with risks in any given industry to a wider field of economic activity.



KEY RISK MITIGATION MEASURES IN MINING, OIL AND GAS EXTRACTION:

- Deep understanding of geopolitical changes and trends, which have a serious influence on the business of extraction companies.
- Maintaining good and stable relations with the authorities in countries and regions where prospecting for mineral resources is taking place - in order to obtain and control low-cost and resource-rich deposits.
- Developing strong relations with local authorities, local community leaders, NGOs and environmental advocates and the local population, so that mineral deposits can be developed over the long term with broad local support.
- Monitoring changes in the legislation and regulation of extraction companies and associated businesses, along with lobbying efforts to push for a good compromise between the interests of business and those of the wider society.
- Predicting or even conducting market-making of prices on commodities, the majority of which are determined by quotation.
- Careful selection and retention of highly qualified staff with the skill and discipline to operate highly sophisticated industrial objects safely.
- Focusing on the reliability and safety of production sites in order to reduce workplace incidents, and minimize the chance of larger industrial accidents - which could become nationwide disasters, cause widespread contamination and incur tremendous expenses for recovery.
- Closely cooperating with national and regional law enforcement to ensure physical and cyber protection of production sites and logistics from any action by third parties.
- Securing long-term and low-cost investment resources to provide for capital-intensive development even in the event of global economic obstacles, rapid changes in demand for mineral resources, etc.

KEY RISK MITIGATION MEASURES IN FINANCIAL AND INSURANCE SERVICES:

- Maintaining an excellent relationship with other participants in economic activity so that they trust the financial institution at all times.
- Development of cooperative relations with the authorities, because the activity of financial institutions influences the national and even international economy and should therefore be regulated properly.
- The ability to provide customers with reasonably priced services or lucrative profits, without violating the regulatory framework or the solvency and soundness of the institution.
- Careful selection and retention of honest-minded and highly-qualified staff, and complex and detailed oversight over those staff.
- Careful selection of borrowers and clients.

KEY RISK MITIGATION MEASURES IN PROFESSIONAL SERVICES:

- Ongoing assessment of the quality and adequacy of advice and solutions provided by professional services staff towards corporate clients.
- The ability to attract and retain the best minds in a field, and motivate them to develop unique and unbeatable ideas and solutions.

In conclusion, we can certainly advise that risk specialists should avoid blindly and hastily taking accident response experience, and risk mitigation measures, from other sectors or subsectors to apply within their own, because of the differences we have described.

Nevertheless, the similarities we have found during the research can help risk specialists to extrapolate risk mitigation experience from one industry to certain others.

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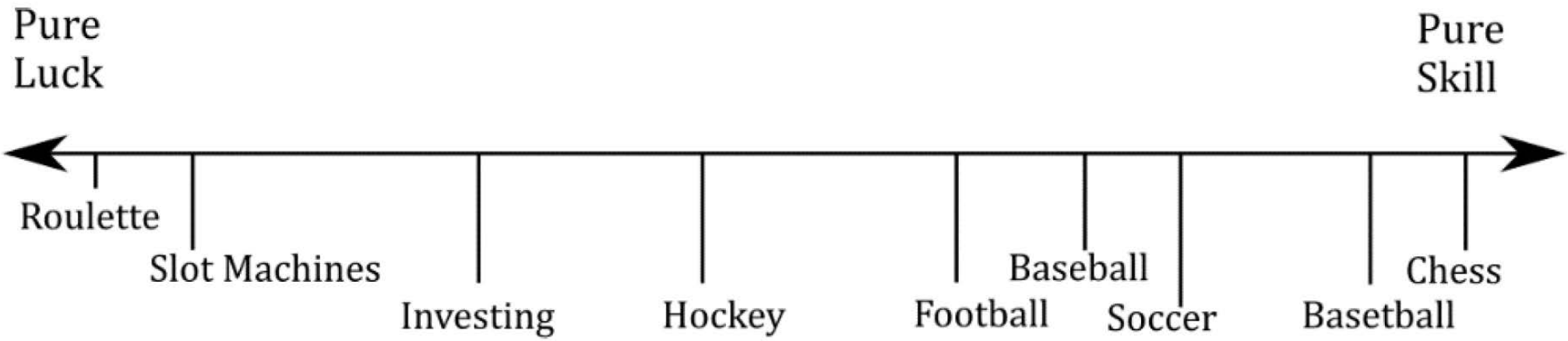
Advances in Complex Systems
Vol. 25, No. 1 (2019) 1950005 (52 pages)

DOI: 10.1142/S021952591950005X

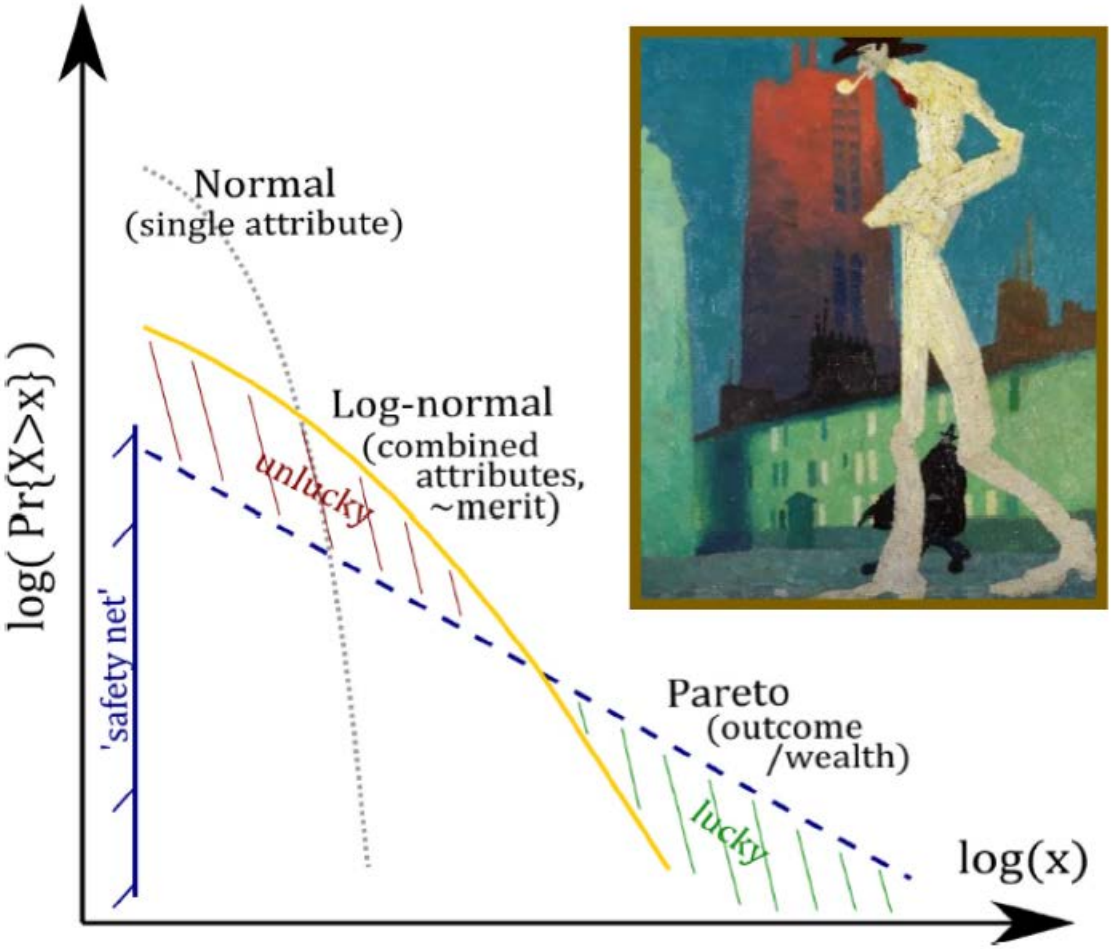
THE FAIR REWARD PROBLEM: THE ILLUSION OF SUCCESS AND HOW TO SOLVE IT

DIDIER SORNETTE*, SPENCER WHEATLEY
and PETER CAUWELS



Different activities in sports, investments, and gambling, ranked on the skill-versus-luck continuum (adapted from Mauboussin)

The skill–success gap



The tails of the normal, log-normal, and Pareto distributions are given in double logarithmic scale. The gaps between the log-normal, as a model for productivity or merit, and the Pareto, measures the skill–success gap", comprising lucky and unlucky groups. Inset is “The White Man”, by Lionel Feininger (1907) of the Carmen Thyssen-Bornemisza Collection (Inv. No. CTB.1972.15).

Mechanisms of Luck

- Gibrat's law, proportional growth, and the Matthew effect
- Winner-takes-all
- Adverse selection
- Male– male competition and evolution
- Heads, I win (it is skill). Tails, you lose (it is bad luck)
- Big statistics replication crisis
- Hyped big data, artificial intelligence, and machine learning

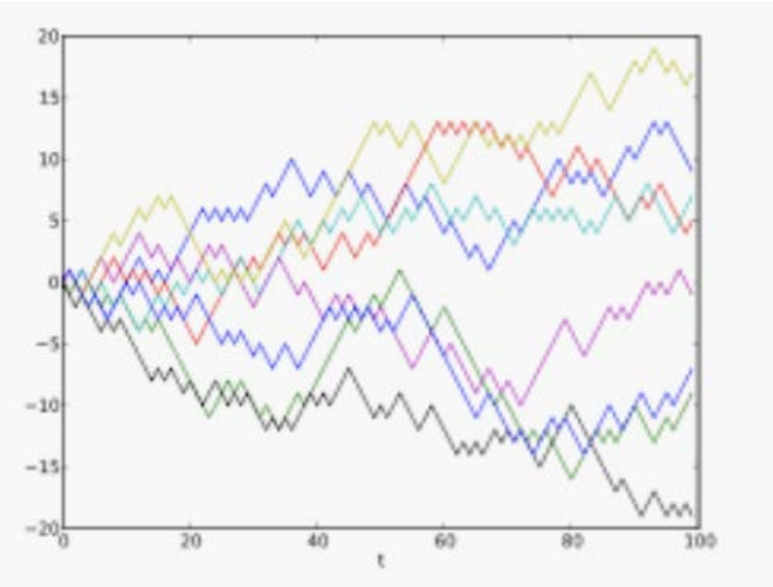
Leinweber, a portfolio manager sifted through a United Nations CD-ROM and discovered that historically the single best prediction of the Standard & Poor's 500 stock index was butter production in Bangladesh. As a practical joke, he published this finding, and claims that people still earnestly contact him, trying to exploit this miraculous correlation.

Skill versus luck

$$\frac{dS_t}{S_t} = \mu dt + \sigma dW_t \qquad \ln[S_t] \sim \left(\mu - \frac{\sigma^2}{2}\right)T + x_i \sigma \sqrt{T}$$

x is rv N(0,1)

- μ_{skill}, the mean of the skills of the N agents;
- σ_{skill}, the standard deviation of the skills of the N agents;
- μ_{luck}, the mean of the luck of the N agents;
- σ_{luck}, the standard deviation of the luck of the N agents.



There is a *characteristic time* T^* at which skill and luck will contribute equal the outcome of the GBM process. At that time T^* satisfies $\mu T^* = \sigma\sqrt{T^*}$, yield

$$T^* = \left(\frac{\sigma}{\mu}\right)^2. \tag{4}$$

Didier Sornette, Spencer Wheatley and Peter Cauwels, The fair reward problem: the illusion of success and how to solve it, Advances in Complex Systems 22 (3), 1950005 (52 pages) (2019), (http://arxiv.org/abs/1902.04940 and http://ssrn.com/abstract=3377177)

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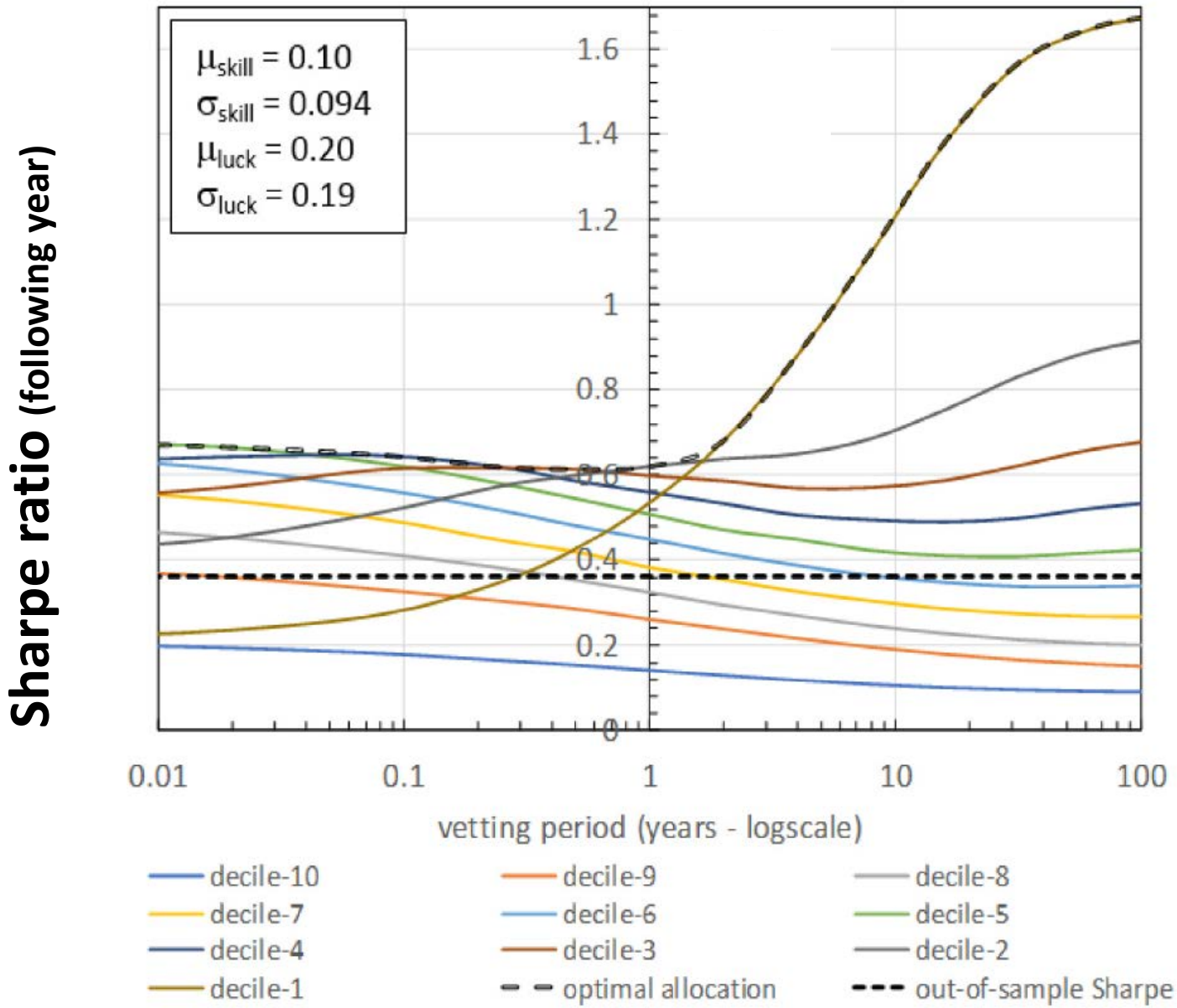
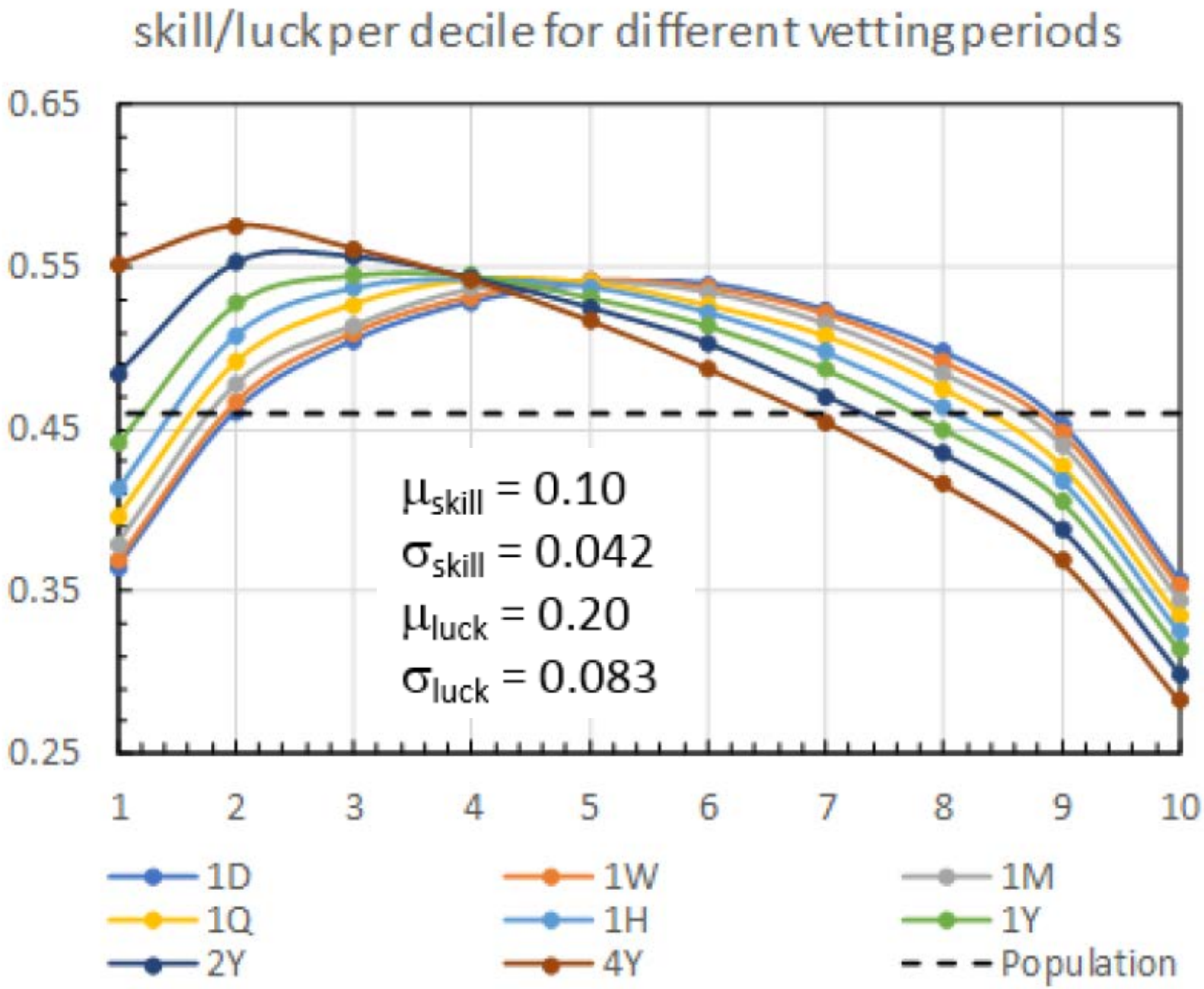


Sharpe ratio (following year)



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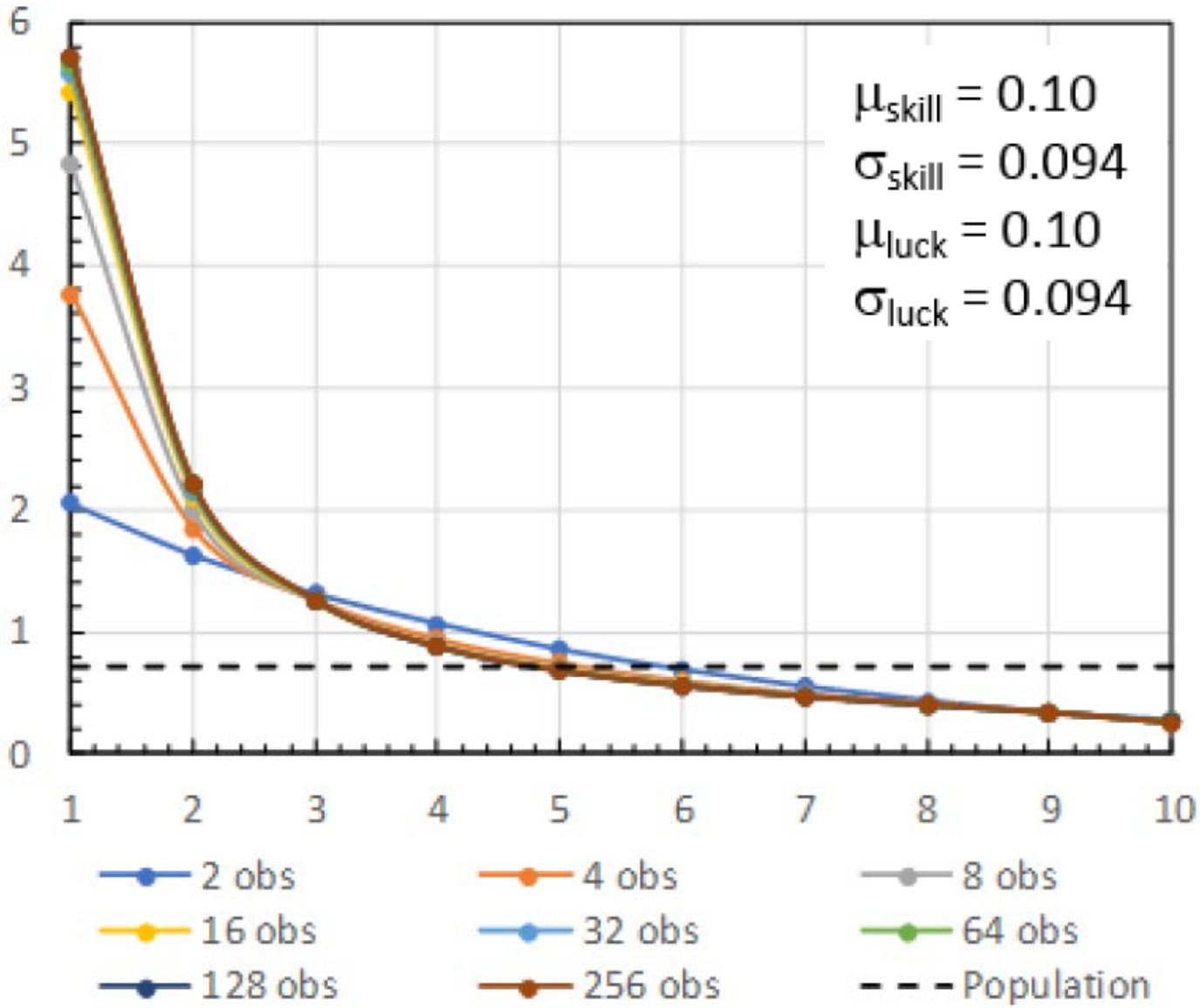
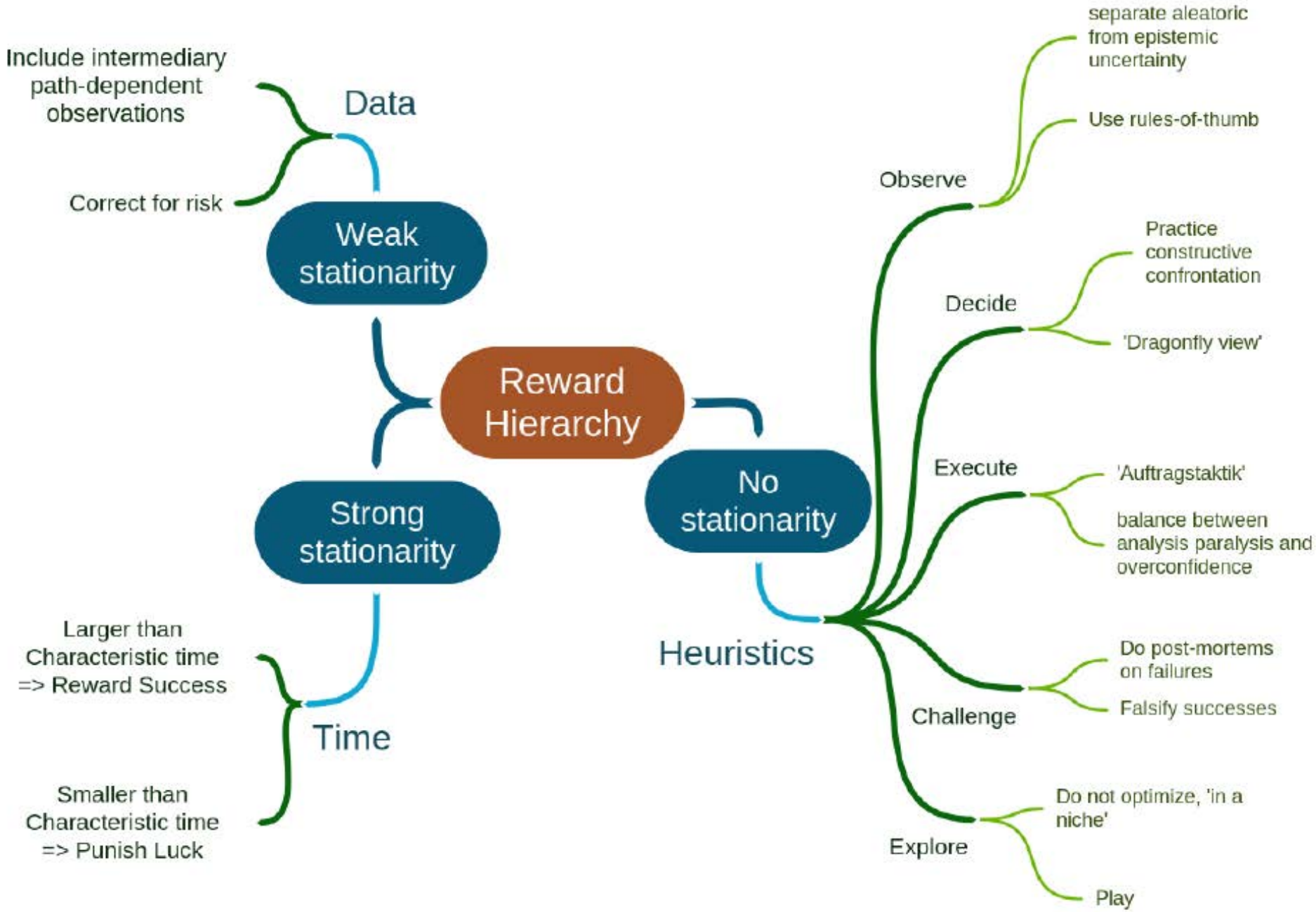
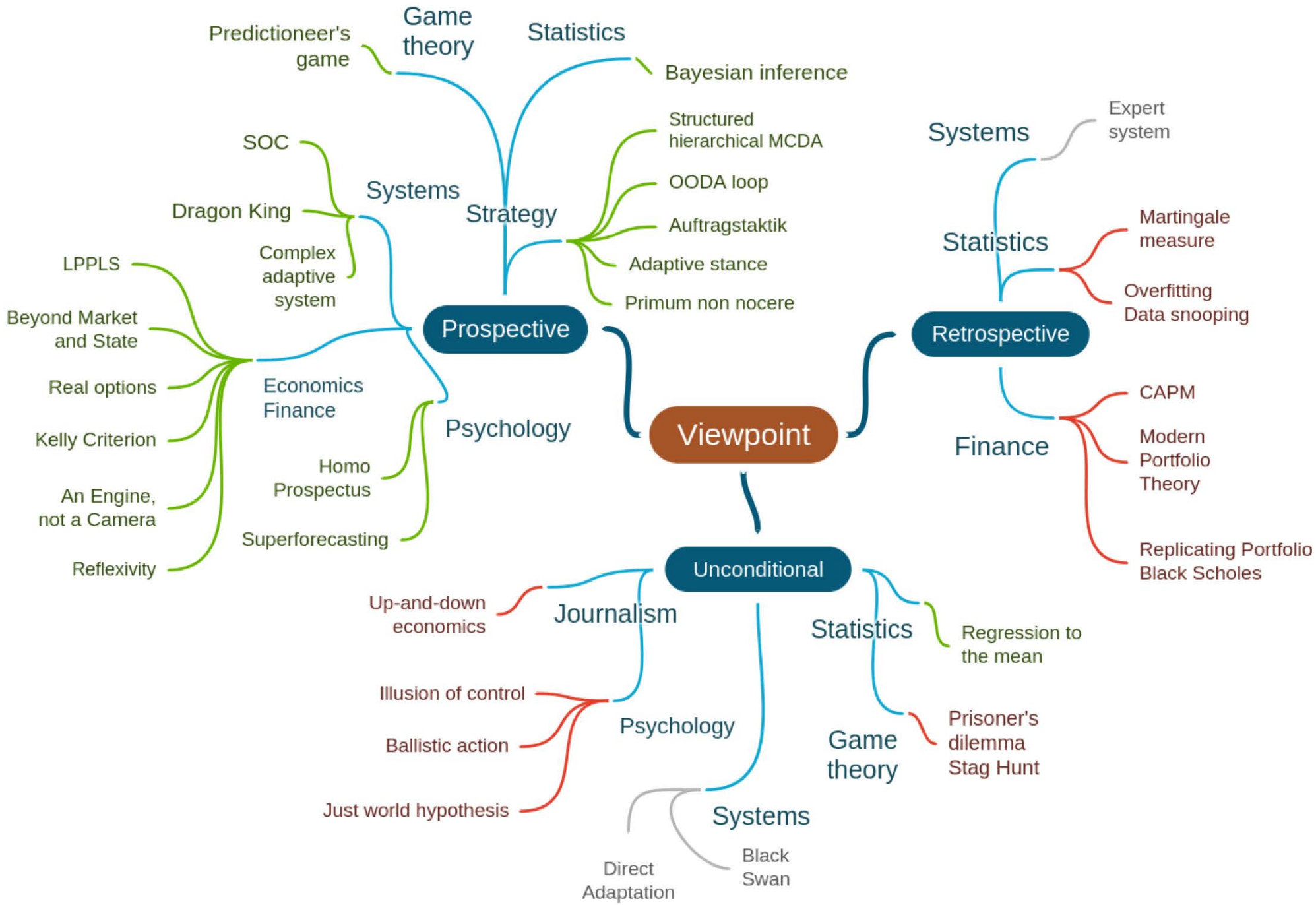


Only if one has the luxury of very long vetting periods, can one separate skill from success in this way: in a stochastic and heterogeneous world, the cream rises slowly.



Three complementary branches representing fundamentally different approaches towards reward. In case of strong stationarity, (life-)time should be used, for weak stationarity, this should be data, and when there is no stationarity, one should apply heuristics.



A multi-disciplinary view of tools and systems from the literature classified according to viewpoint. The green-colored are fully aligned with the environment, the red-colored do not take insufficient stationarity into account, and the gray-colored are just tools.

Time-at-Risk

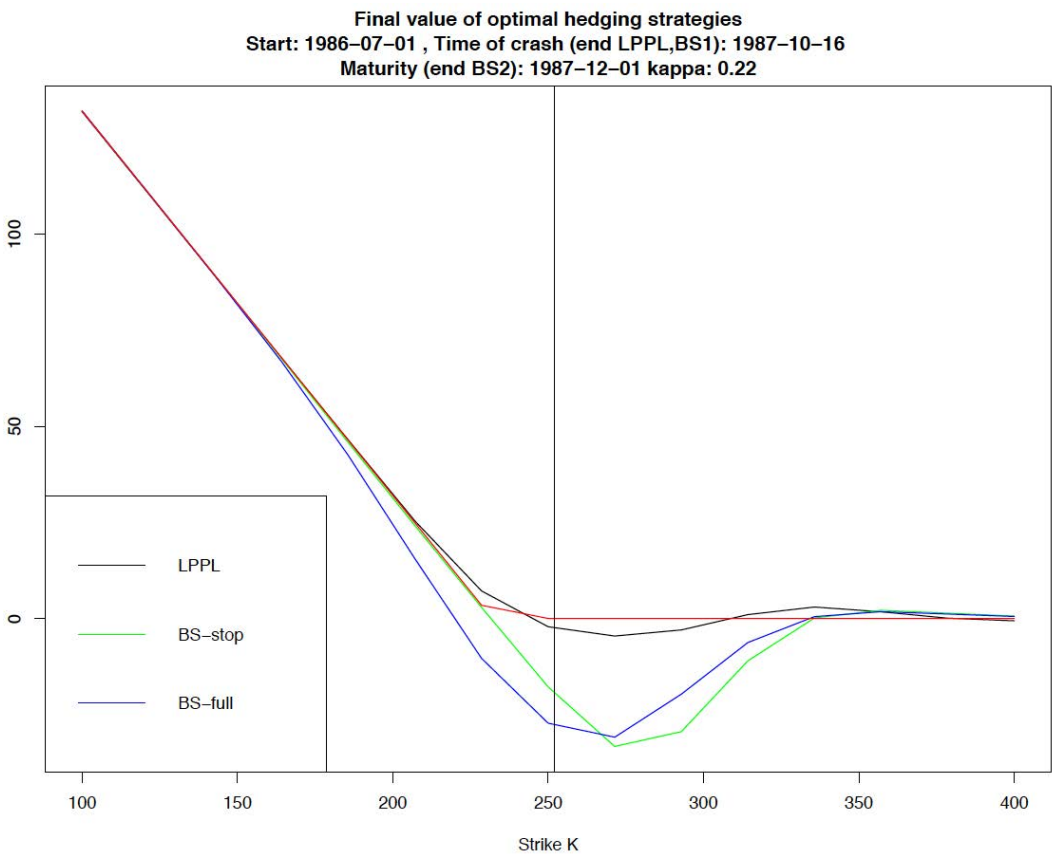
M. Schatz and D. Sornette (working paper)

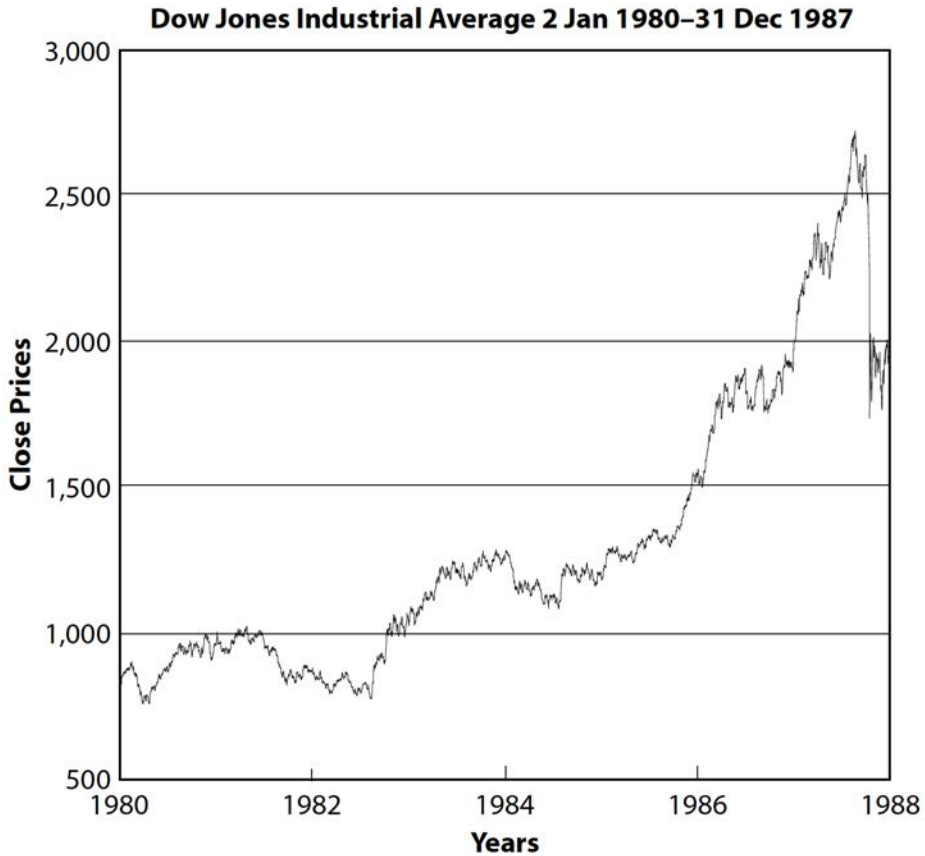
theory of option pricing in incomplete markets to calculate fair values and hedging strategies in single jump models with possibly explosive drift.

$$E_{\mathbb{Q}_t}\left[(S_{T_C}-K)^+\right] = \mathbb{1}_{\{\tau_J \leqslant t\}}(\tilde{S}_{\tau_J}(1-\kappa)-K)^+ + \mathbb{1}_{\{t<\tau_J\}}\left[\tilde{S}_t\phi_t - K\psi_t\right]$$

$$\phi_t = (1-\kappa)\int_t^T e^{(1-\kappa)(\Gamma_t-\Gamma_u)}\Phi(d_1(u))h(u)du + e^{(1-\kappa)(\Gamma_t-\Gamma_T)}\Phi(\widehat{d_1})$$

$$\psi_t = \int_t^T e^{\Gamma_t-\Gamma_u}\Phi(d_2(u))h(u)du + e^{\Gamma_t-\Gamma_T}\Phi(\widehat{d_2}) \qquad \Gamma_t^{\mathbb{P}} = \int_0^t h^{\mathbb{P}}(s)ds.$$





Methodology for diagnosing bubbles

The Log-Periodic Power Law (LPPL) model

- Positive feedbacks of higher return anticipation
  - Super exponential price
  - Power law "Finite-time singularity"
- Positive feedback of negative spirals of crash expectation
  - Accelerating large-scale financial volatility
  - Log-periodic discrete scale-invariant patterns

Expectation component of the price dynamics:

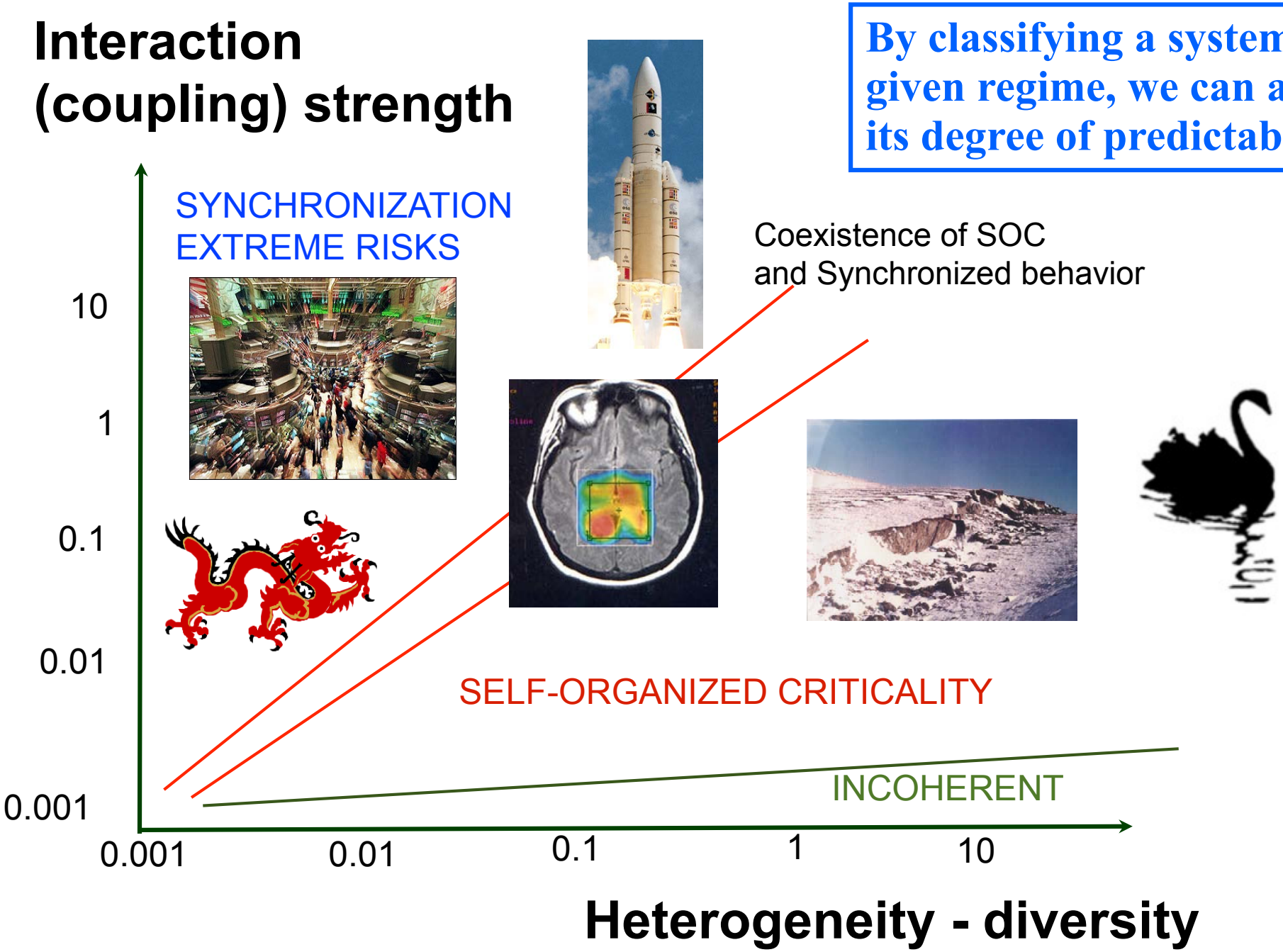
$$\ln(P) = \overset{1}{\boxed{A + B\,(t_c - t)^m}} + \overset{2}{\boxed{C\,(t_c - t)^m}} \cos\left(\overset{3}{\boxed{\omega \ln[t_c - t]}} - \phi\right)$$

A. Johansen, D. Sornette and O. Ledoit
Predicting Financial Crashes using discrete scale invariance,
Journal of Risk, vol. 1, number 4, 5-32 (1999)

A. Johansen, O. Ledoit and D. Sornette, Crashes as critical points,
International Journal of Theoretical and Applied Finance Vol. 3, No. 2
219-255 (2000)

Generic Risk Prediction Phase Diagram

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



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Highlights

- Dynamical approach: see and quantify movies rather than snapshots
- Innovation and entrepreneurship is based on regime shifts and change of regimes that are the “norm” rather than the exception and will be growing in the future.
- Markets exhibit transitions between phases of growth, exuberance and crises.
- Most successes and crises are endogenous and are the consequence of procyclical positive feedbacks that are not sustainable but part of the creative process.
- Based on a solid monitoring infrastructure, a dynamical time@risk management based on scenarios is possible by recognizing the ubiquitous positive feedbacks and “pockets of predictability”.