Econophysics & Big Data

- broadbrush today....details in http://polymer.bu.edu/~hes/
- work by (one could wish no finer collaborators):

Gabaix (Fisher-Black Prize!), Salinger, Pammolli, Riccaboni, Podobnik, Preis, Moat, Vodenska, Buldyrev, Havlin, Mantegna, Gopikrishnan, Plerou (Young Scientist Prize), Petersen, Liu, Cizeau, Fu, D. Wang, H. Wang, F. Wang, Bertella, X. Huang, S. Zhang, G. Li, J. Wu, S. Levy, X. Feng, Yamasaki, Rosenow, Amaral, Ivanov, Matia, W-X Zhou, Z. Q. Jiang, Weber, Chessa, Gou, Lee, Meyer, Y-H Shao, Carbone, Ben-Jacob, Kenett, Fu, Majdanzic, Schneider, Curme, Avakian, Su, Lu, S. Shao, Ling, H. Huang,

& YOU [??]

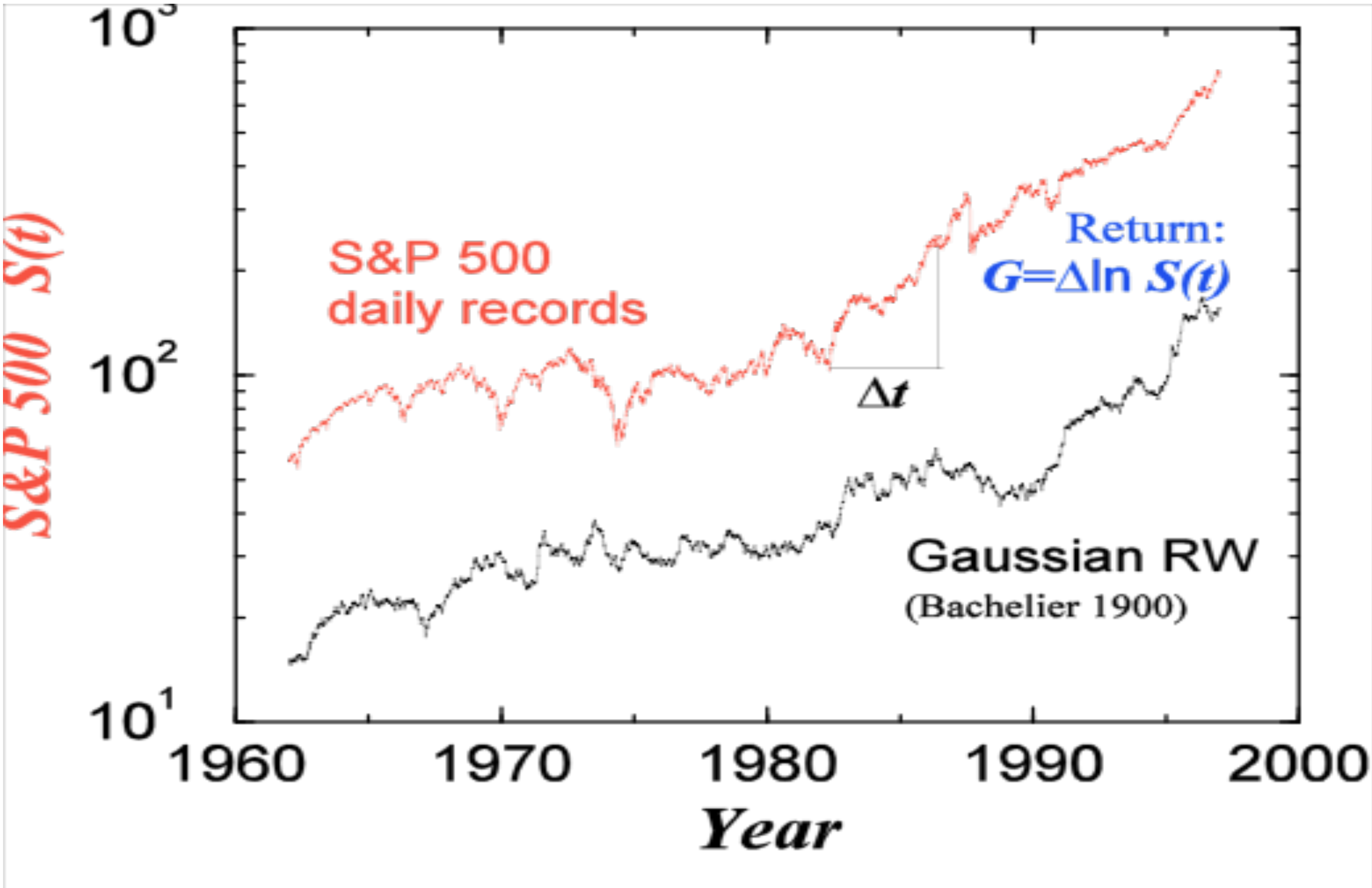
INVITATION: please consider to come to Rm. SCI-204......
i will welcome you at any time!

Can physicists contribute to economics/finance?

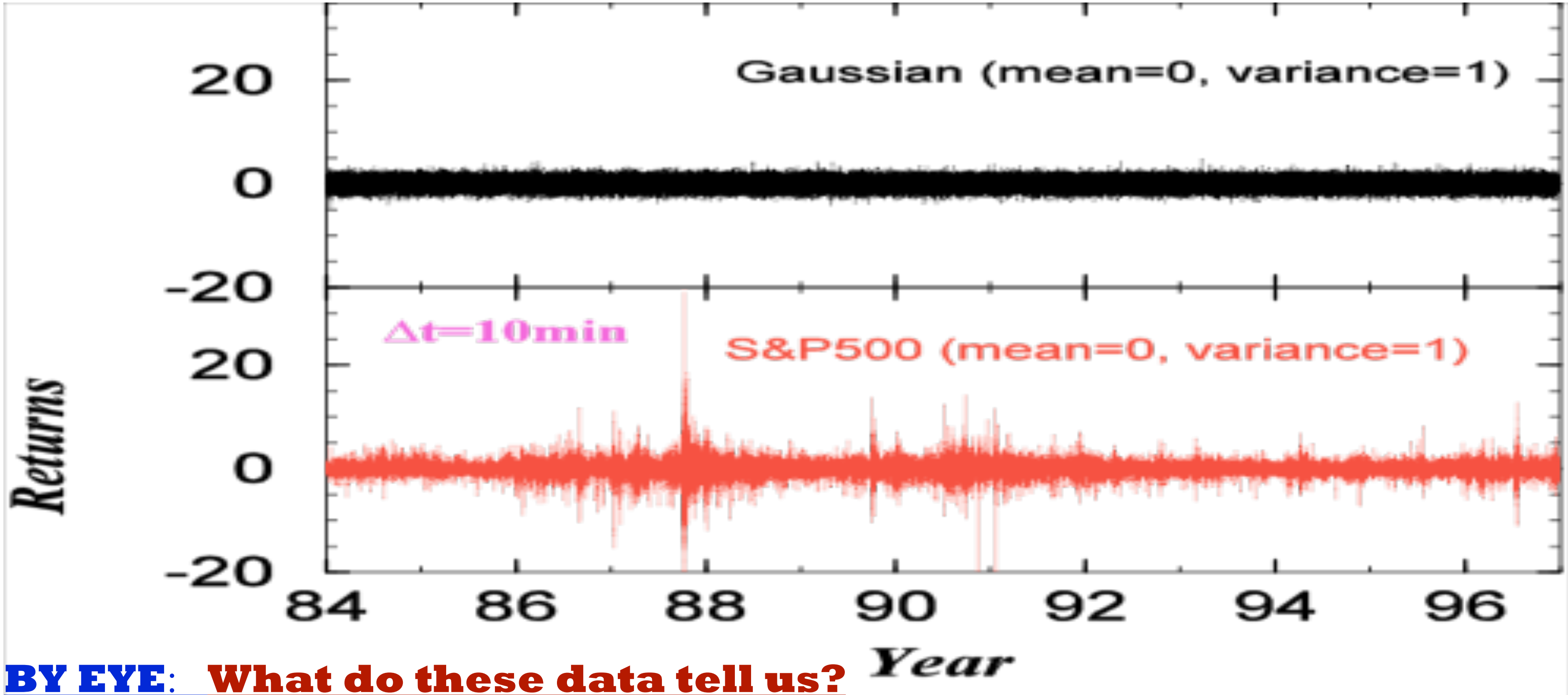
- get an economics partner...& respect him/her!
- get as much data as exists ("big data")
- ask "What are these data telling us?"
- to find out, quantify each finding...
- Do not be too timid: e.g., Aggregate, ...
- try to relate all findings (ex: price, volume, intertrade times, volatility,...)
- Make "model" relating all facts **("cheating"?)**

Dedication: TINBERGEN/EHRENFEST the first econophysicists?

THE PUZZLE: "SWITCHING WITHOUT SWITCHES"



"Big switch" : 19 Oct. 1987 (25% worldwide "earthquake/tsunami")



BY EYE: **What do these data tell us?**

Q: can your **eye** see the power law? that it is inverse cubic?

Returns non-Gaussian (known qualitatively, but under-appreciated!)

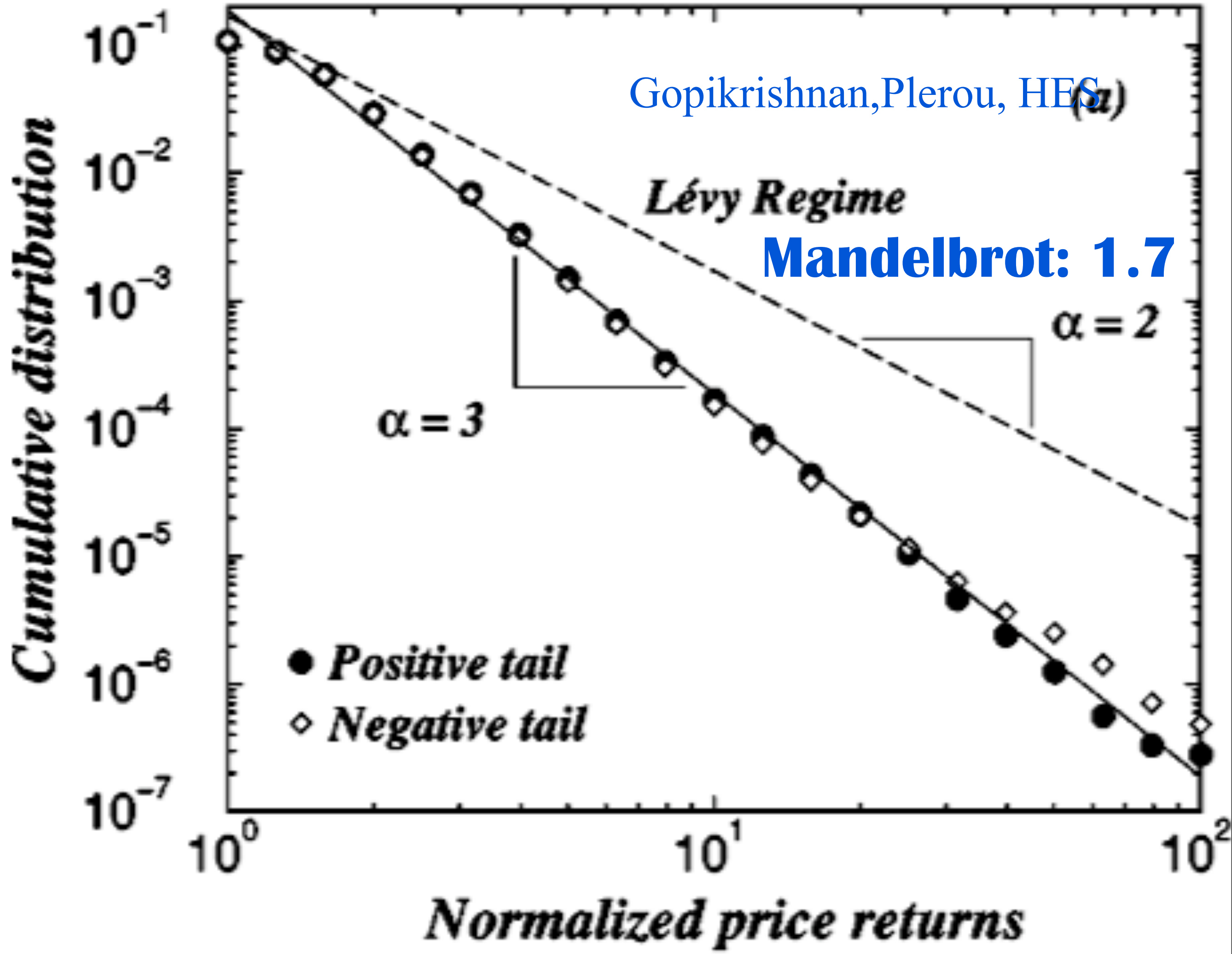
Large events cluster (like earthquakes) (also known qualitatively)

"Aftershocks" Omori-correlated (Palermo 03; BU 07)

"Aftershocks of each aftershock" also Omori-correlated: (BU) holds over **6** orders of magnitude on y-axis (**8** for pdf: inverse quartic)

200,000 data points per stock **x** 1000 stocks =
200,000,000
data points

events 8 orders of magnitude MORE RARE than everyday values conform to the SAME pdf

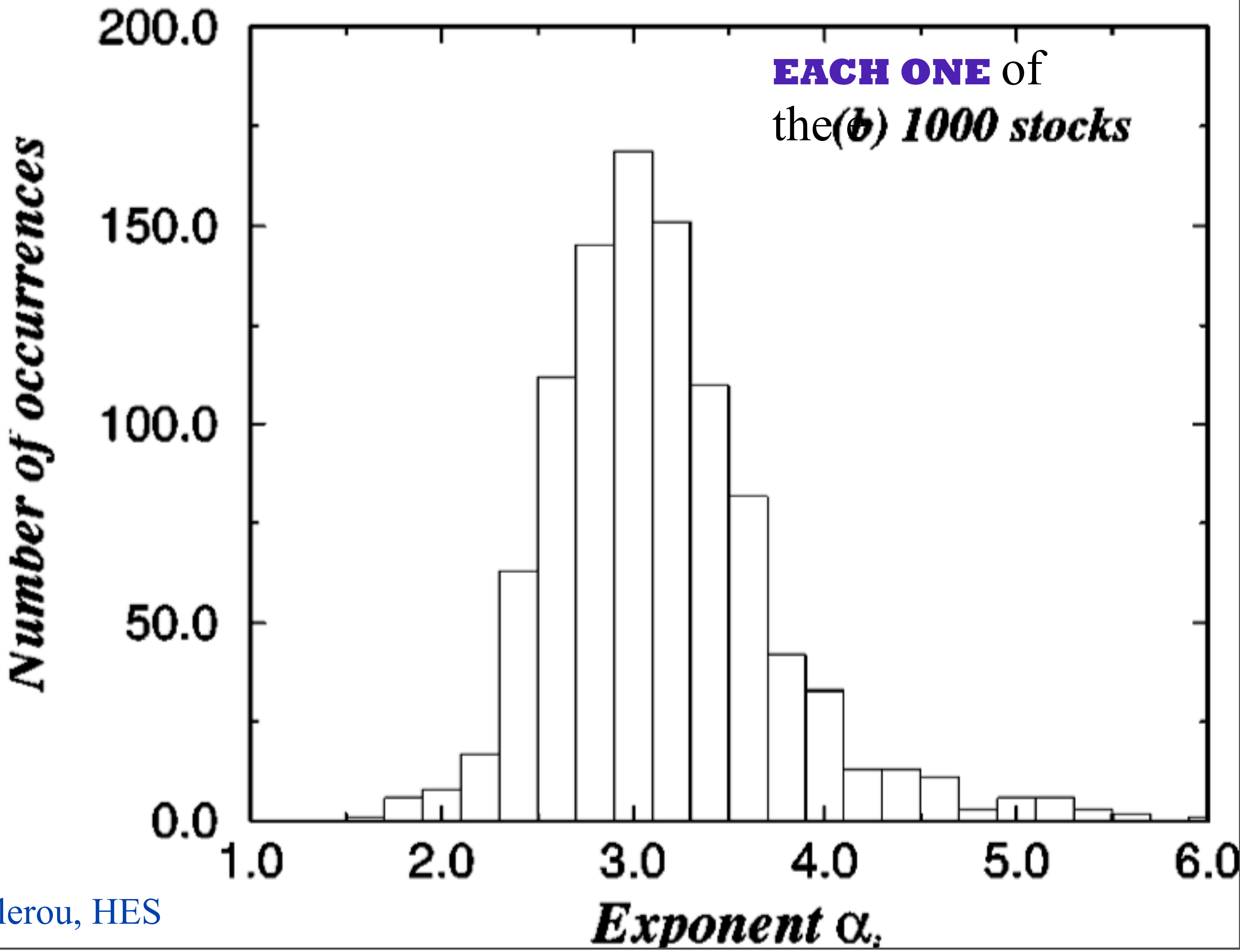


Gutenberg-Richter earthquake law:
mag = 7 quake **same** law as mag = 1 quake

Note: there is NOT a perfect power law due to corrections at both ends of a power law region, just as for power laws in turbulence.

Aggregating is also "cheating"??

Find that inverse cubic law holds "microscopically" for **each stock**



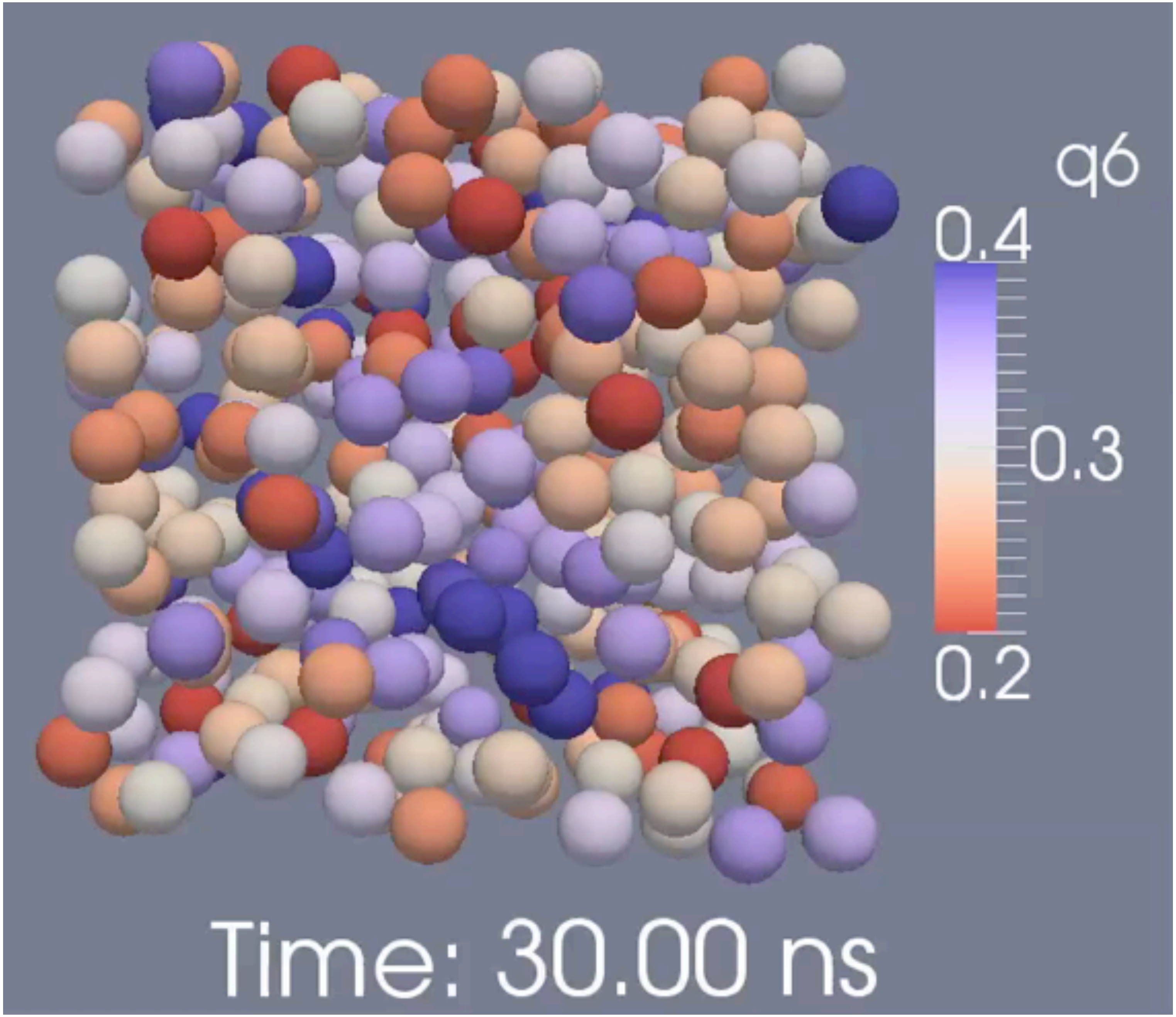
Gopikrishnan,Plerou, HES

The Economist

Text

The Economist

Text


q6
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Time: 30.00 ns

“How?” “Models?”: Herd vs. News?

(1) “herd effect” (exchange int. J). (2) news effect (external field H)

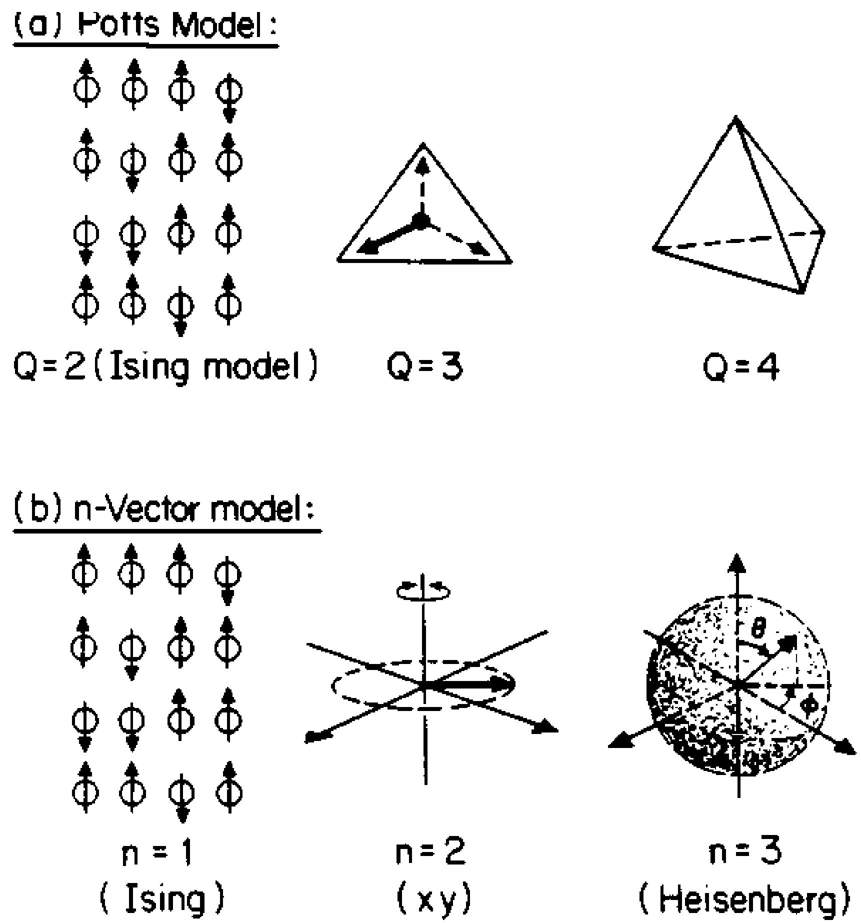
Each stock is a unit, interacting with other stocks (units) and bathed in a magnetic field H. J depends on the two stocks, and H depends on the stock. Both can change with time.

Possible models:

(a) Units can be in Q different DISCRETE states: “Potts Model” (Potts 1952).

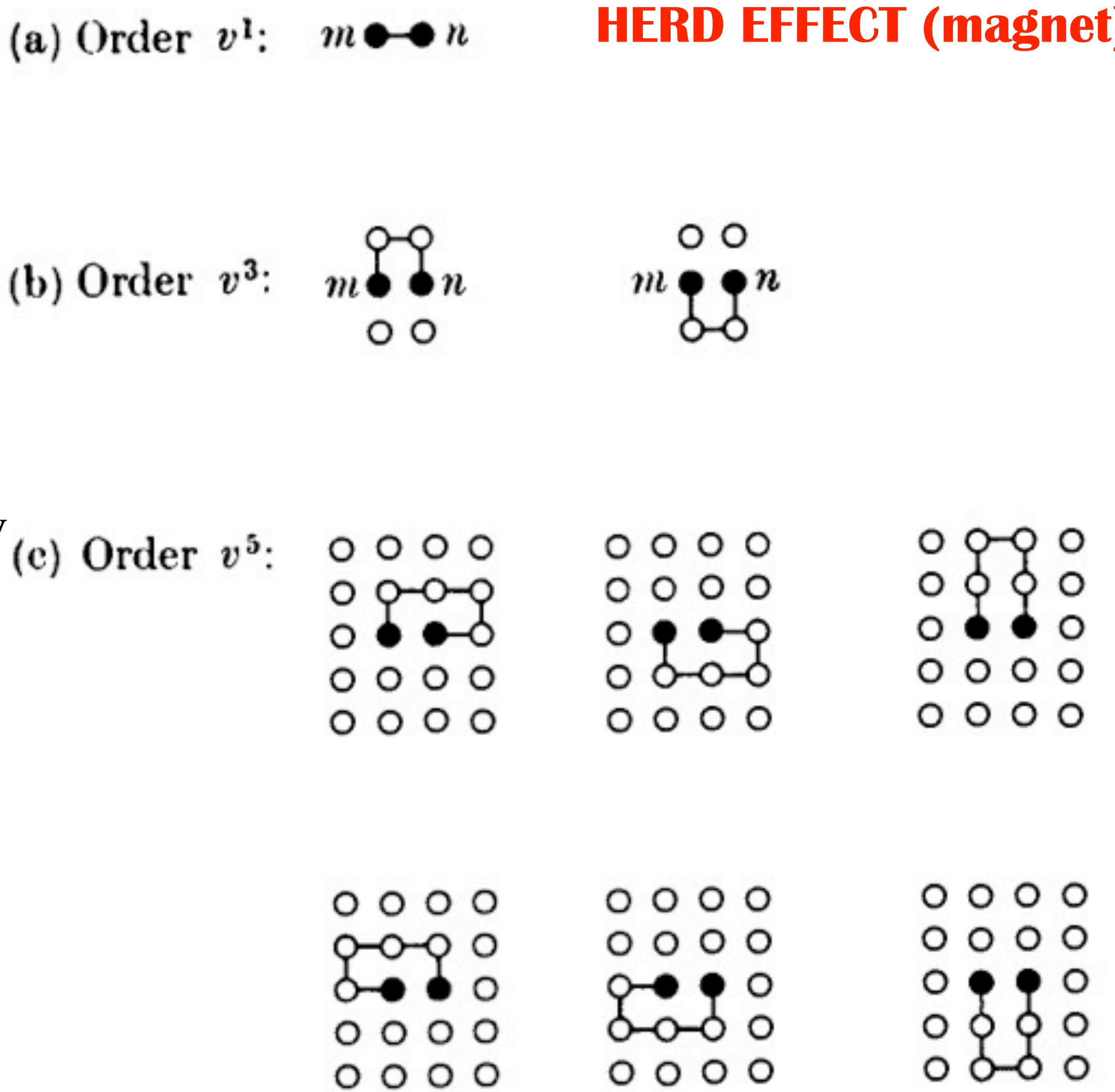
(b) n-dimensional units. Each can be in a CONTINUUM of states: “n-Vector Model” (HES 1969)

(c) modified Edwards-Anderson “spin glass” (w/ t-dep interactions)



PUZZLE:
How does a paramagnet "know" when to spontaneously order itself?

HERD EFFECT (magnet)

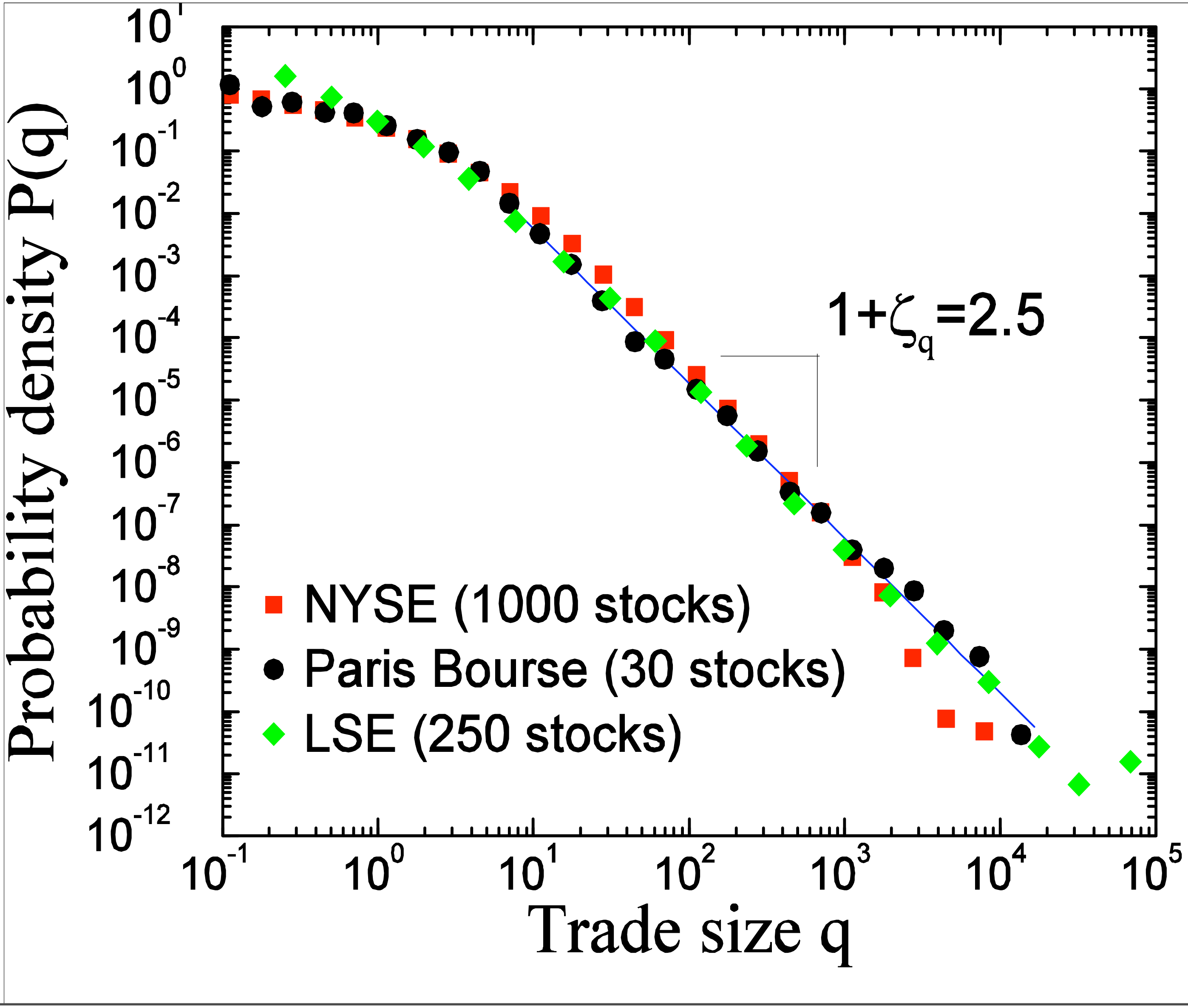


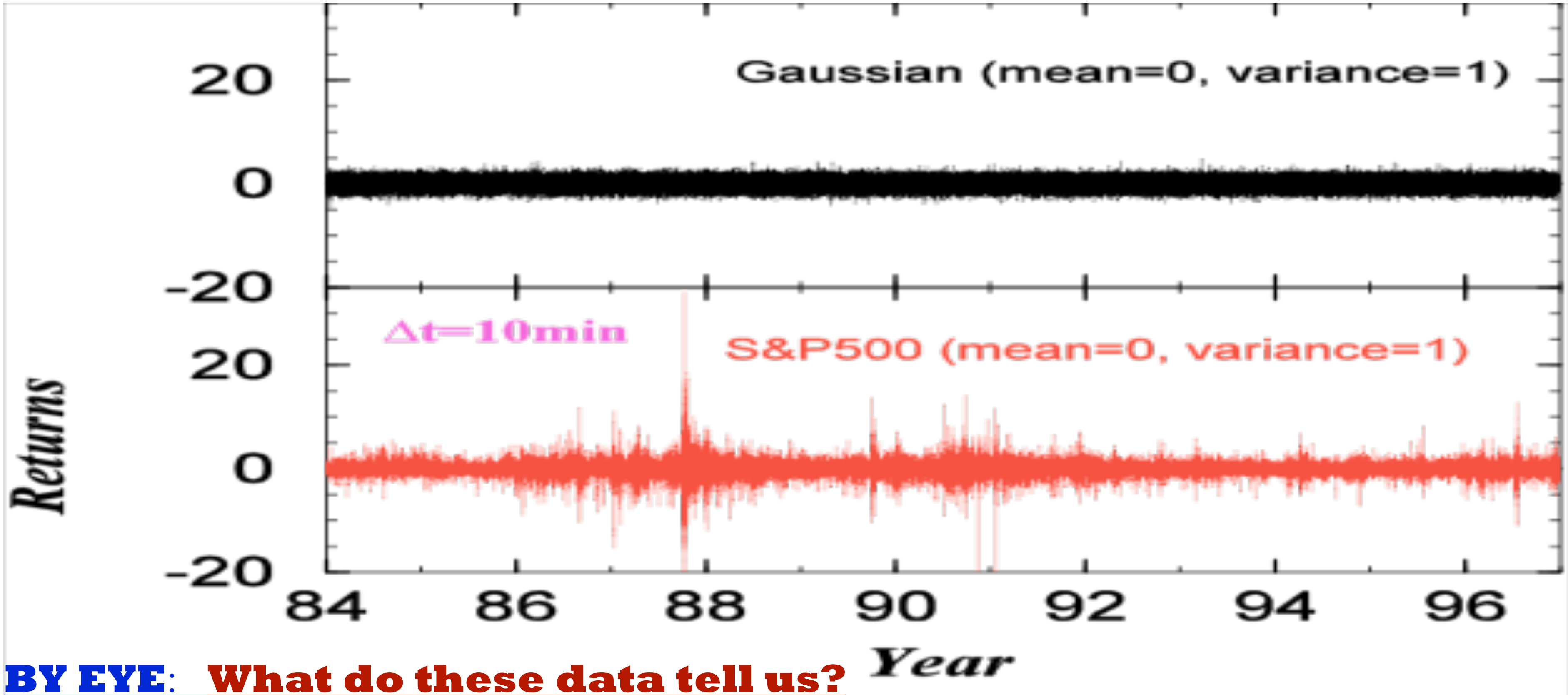
ANSWER:
When the exponential decay along a 1-d path balances the exponential increase in the number of paths.

v = J/kT = n.n. coupling strength

TEST #1: if interacting system of subunits, should be "universality"

DATA Show: power-law exponents are Universal (indep of time period, country, volatility (ex 1987,2008,.. same!). implies what??





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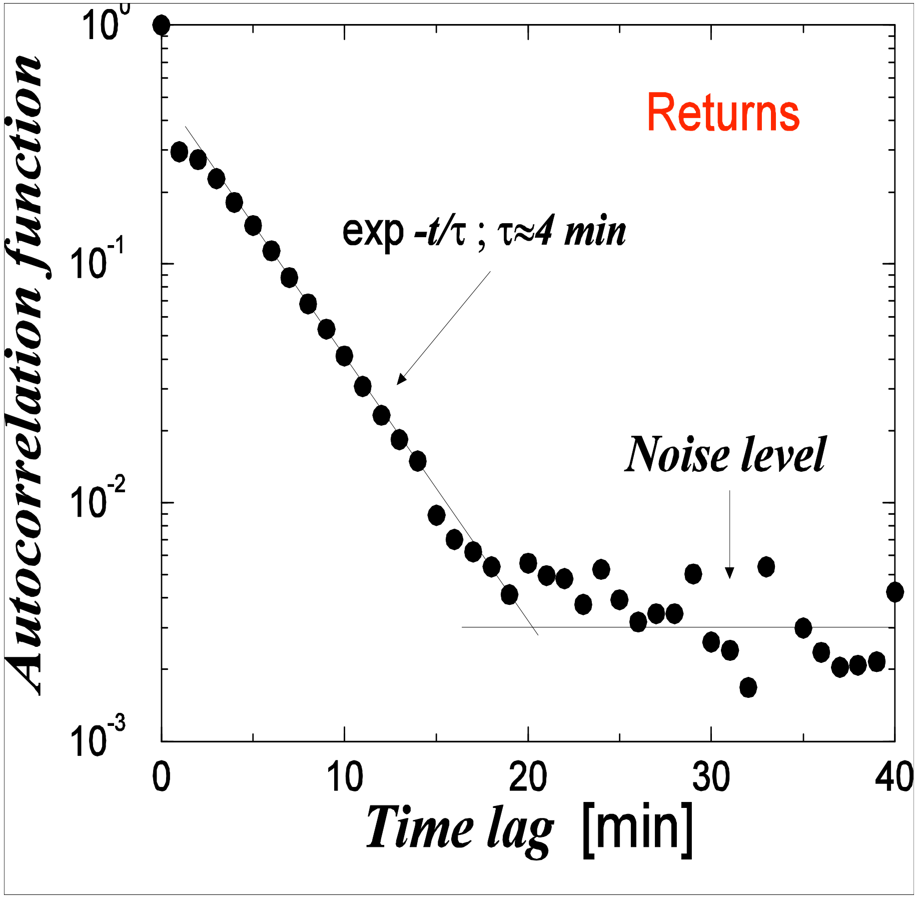
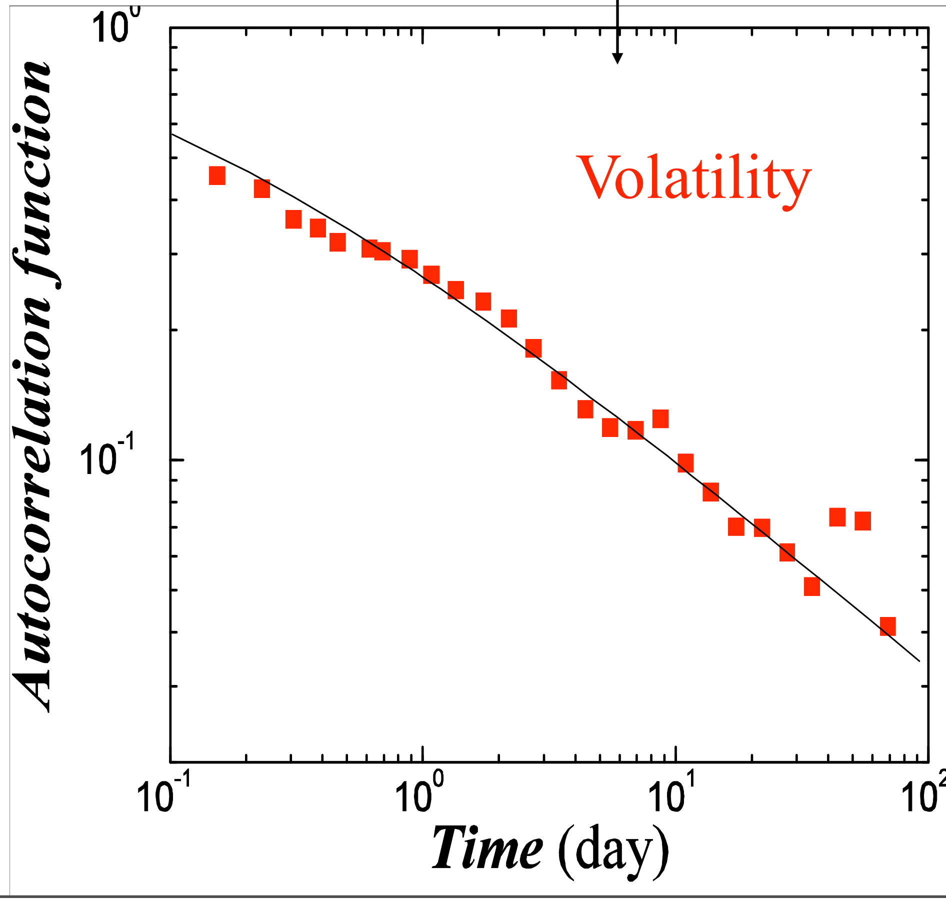
Test 2: Are there time Correlations?

((economists knew these results, qualitatively, as volatility clustering....so calculate autocorrelation function and get a "law"))



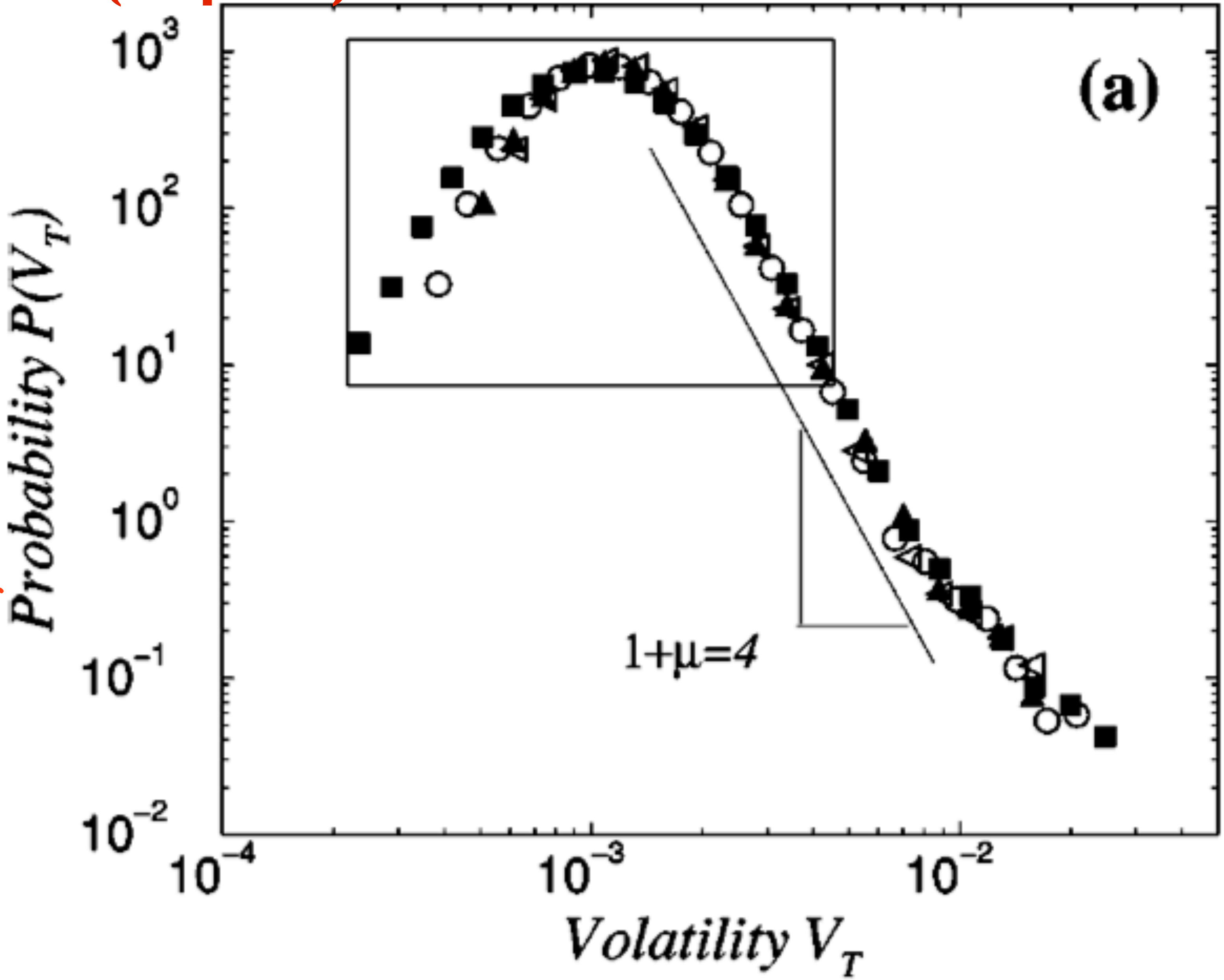
$$R_t = \mathrm{sgn}(R_t) \quad |R_t|$$



- Returns are UN-correlated after 4 min
- Absolute value of returns (volatility) is long range correlated, so returns CAN NOT BE serially independent.

TEST 3: Crossover in Volatility pdf from (known) log-normal to (new) power law **(Surprise!)**

Liu,Cizeau, Meyer.``The Statistical Properties of the Volatility of Price Flucts" Phys. Rev. E 60, 1390.



Can a law describe bubbles and crashes in financial markets?

Goal: every trade---msec level...

Tobias Preis [1,2] and H. Eugene Stanley [1]

Physics World, May 2011

DETAILS IN:

T. Preis, J. Schneider, HES``Switching Processes in Financial Markets," PNAS 108, 7674 (2011).

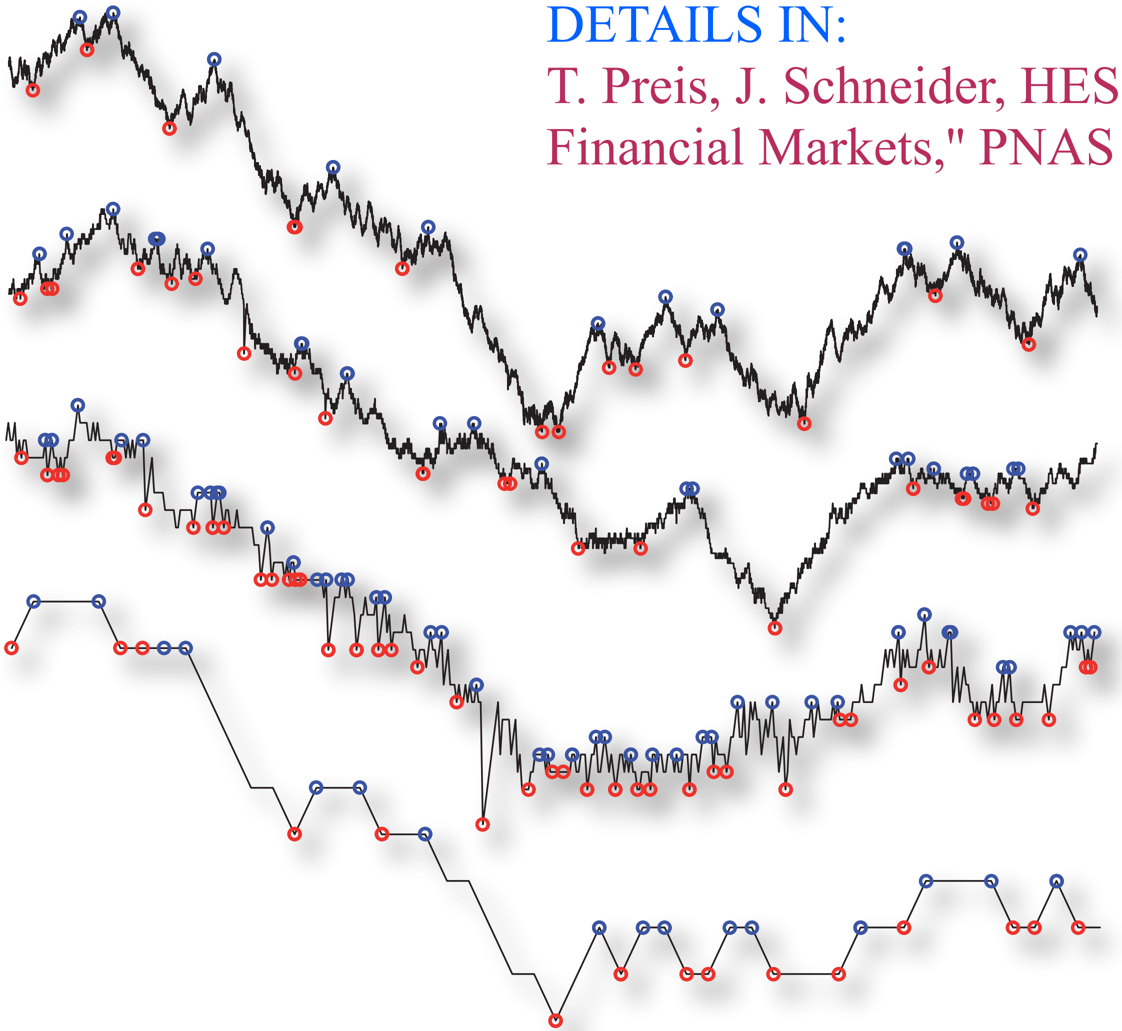
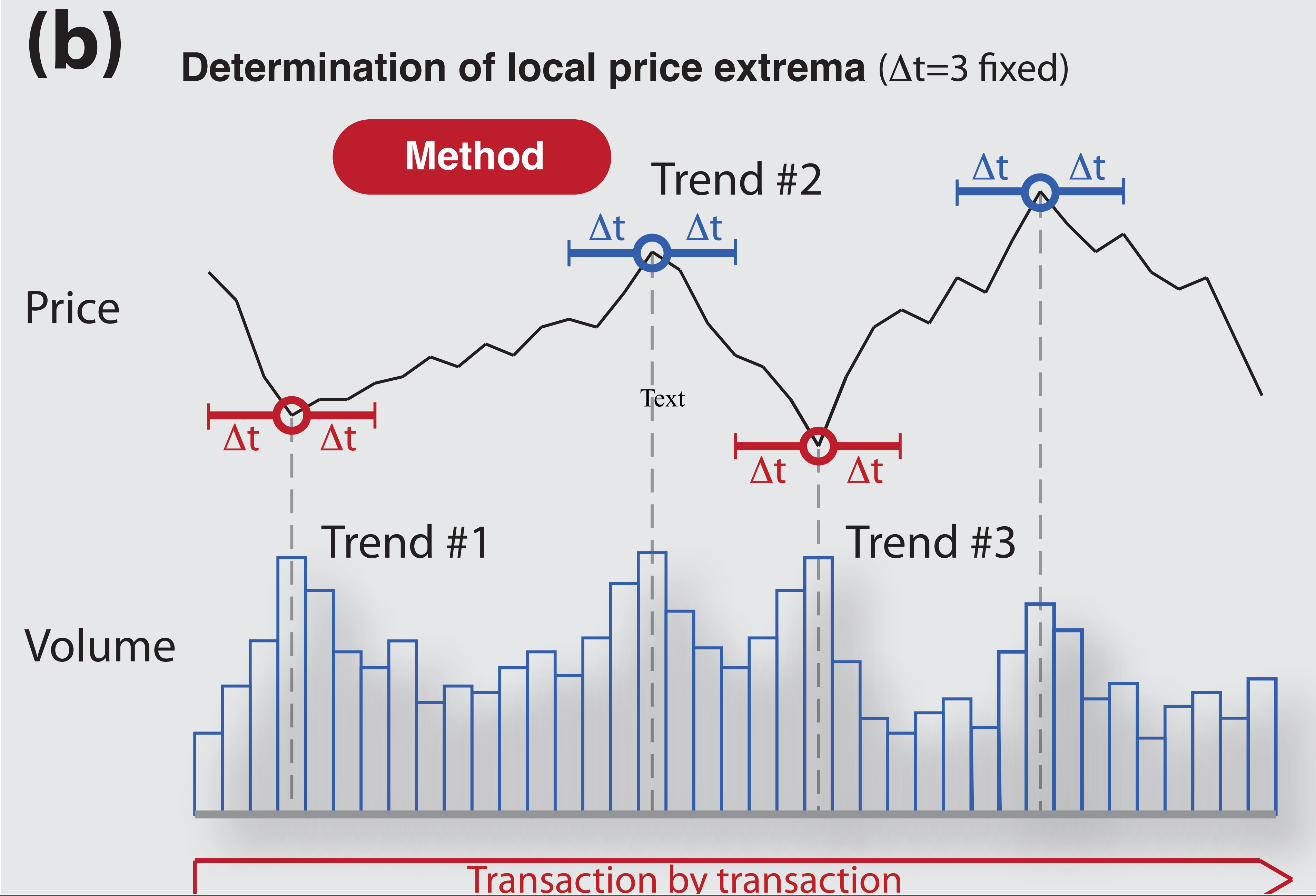


Figure 1 | Scale-free behavior of financial market fluctuations. Financial market time series feature identical properties on very different time scales. All four curves are subsets of a 14 million transactions dataset taken from a German DAX future time series. The price curves cover time periods of roughly 1 day (top curve), 1 hour, 10 minutes, and 1 minute (bottom curve). Local maximum and minimum values are marked as blue and red circles.

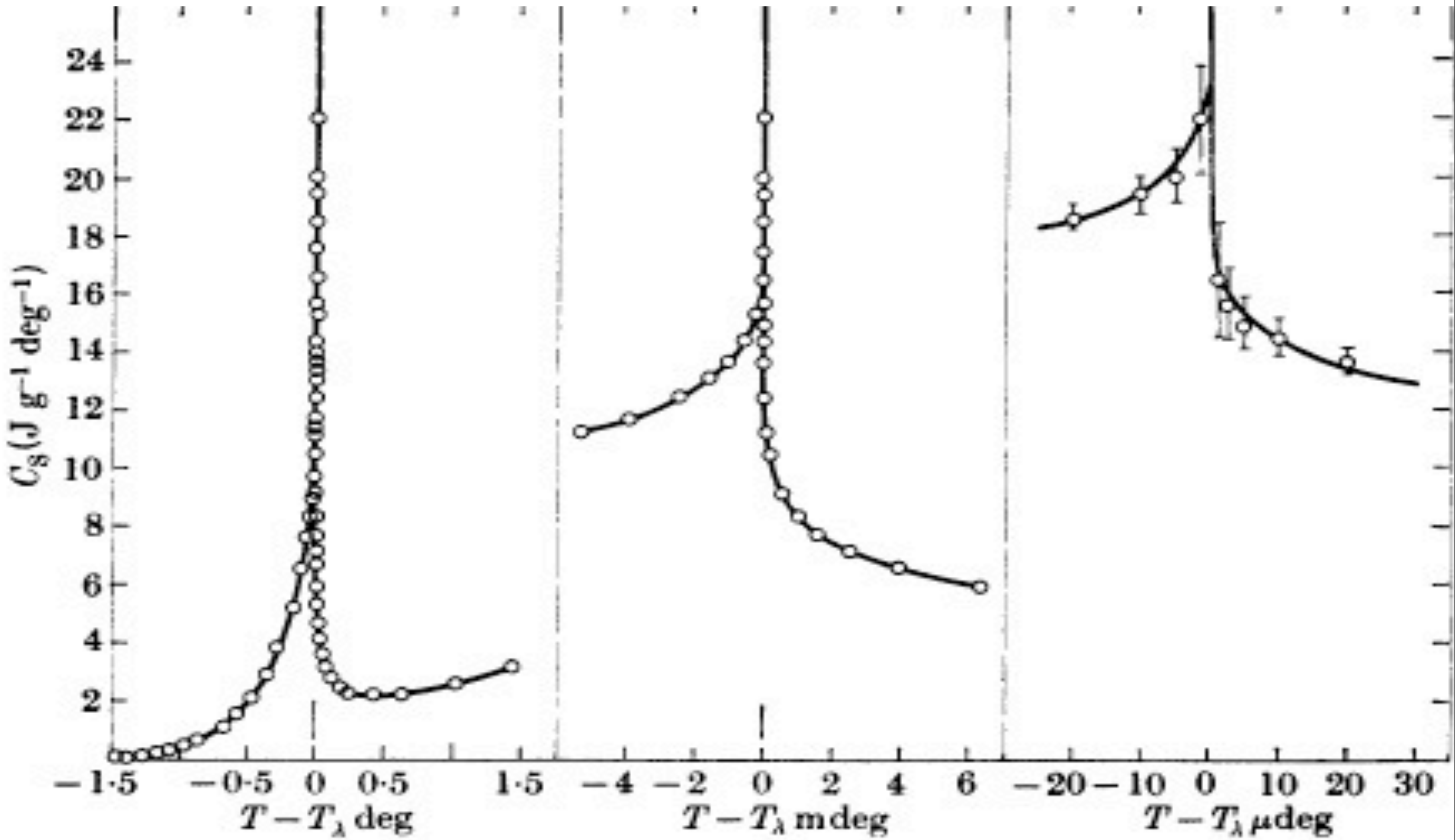
BIG QUESTION: How to quantify/analyze?????

ANS: :: Preis/HES/Schneider (2011 PNAS; May 2011 Physics World)

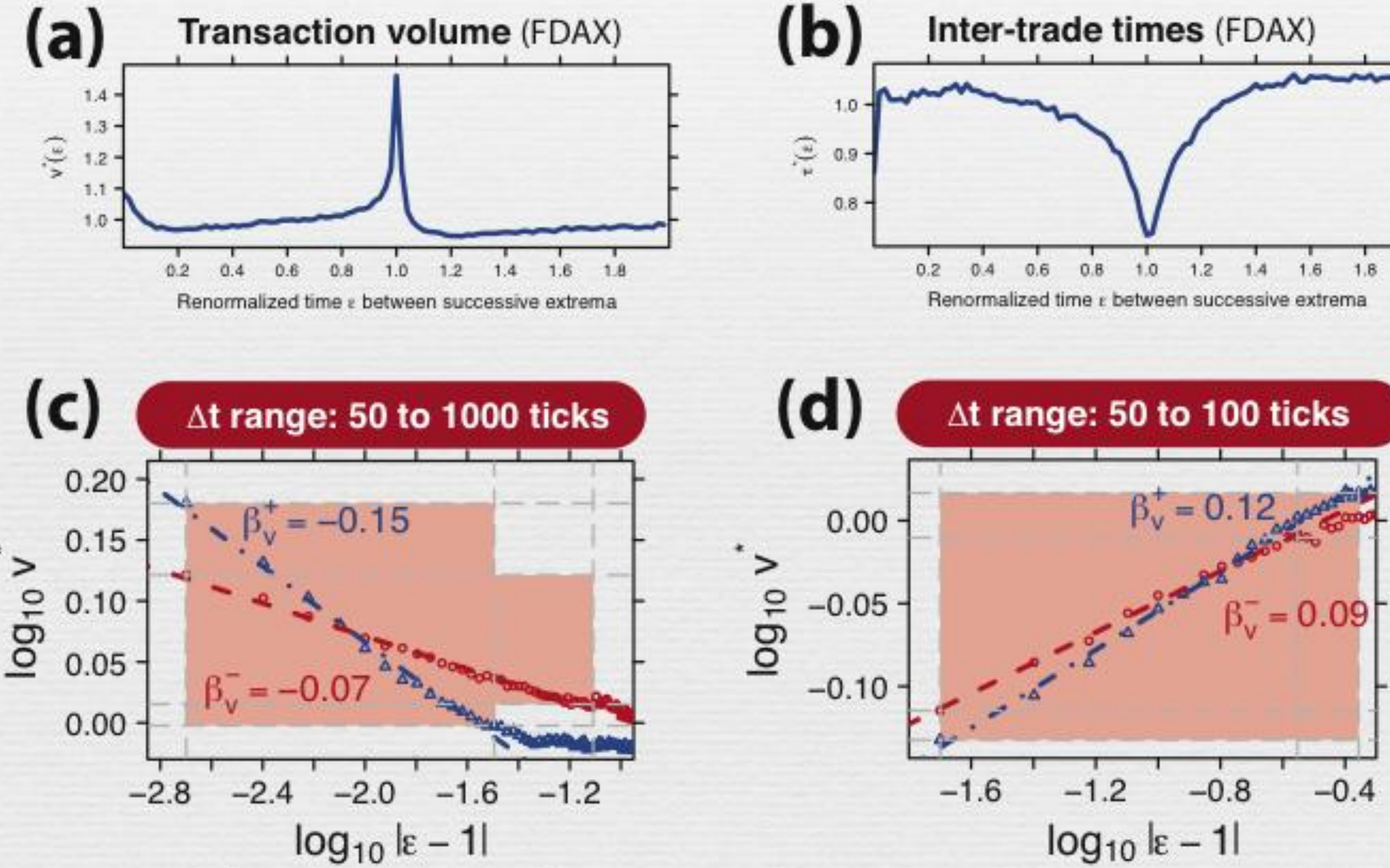


SCALE FREE SPECIFIC HEAT NEAR HELIUM SWITCH POINT

Note: Same FUNCTION for 3 different scales: 6 orders of magnitude!!!



Quantities With Scale-Free Behavior

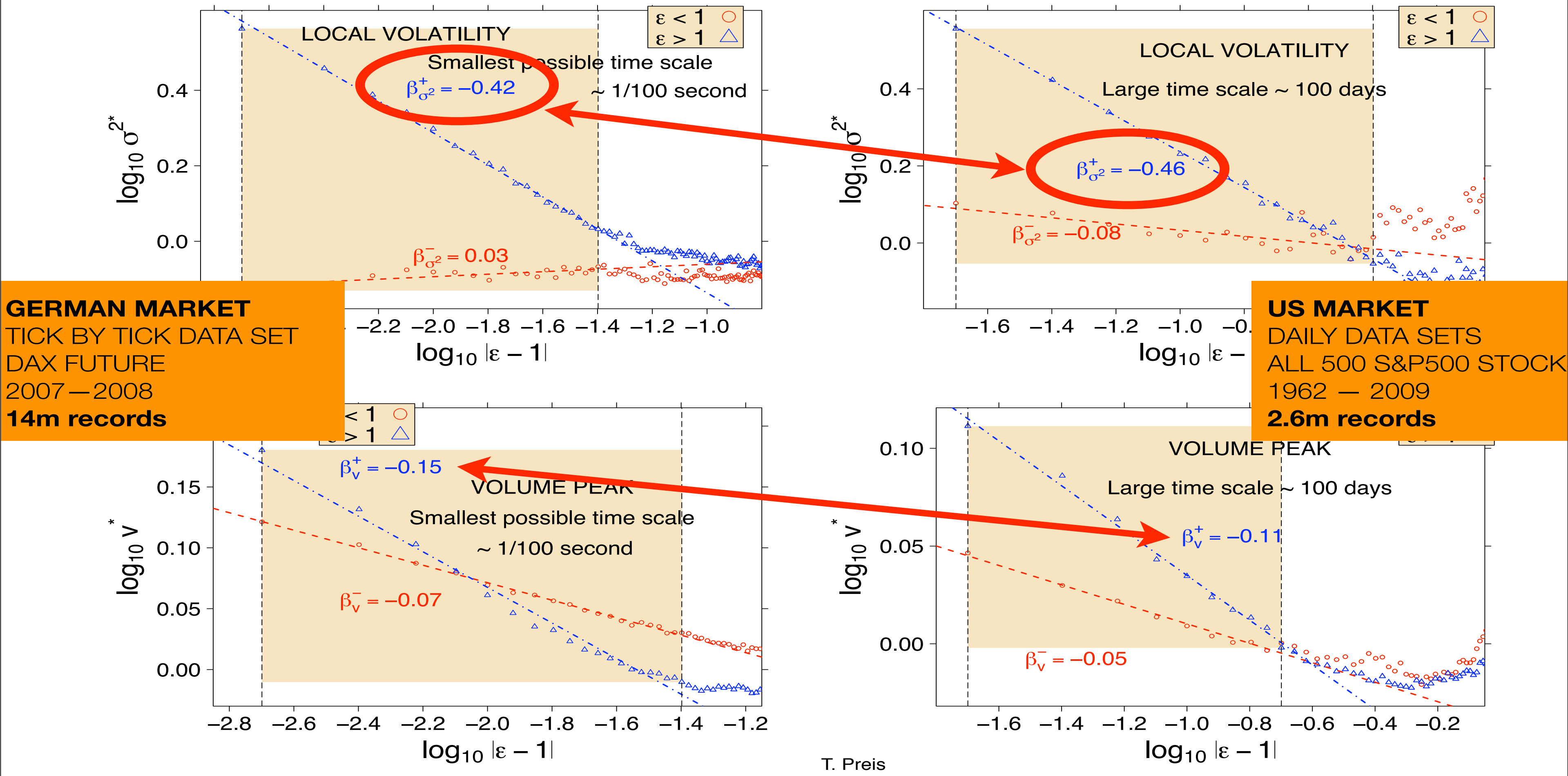


- Randomly reshuffling confirms our findings.

Preis/HES/Schneider (2011 PNAS; May 2011 Physics World)

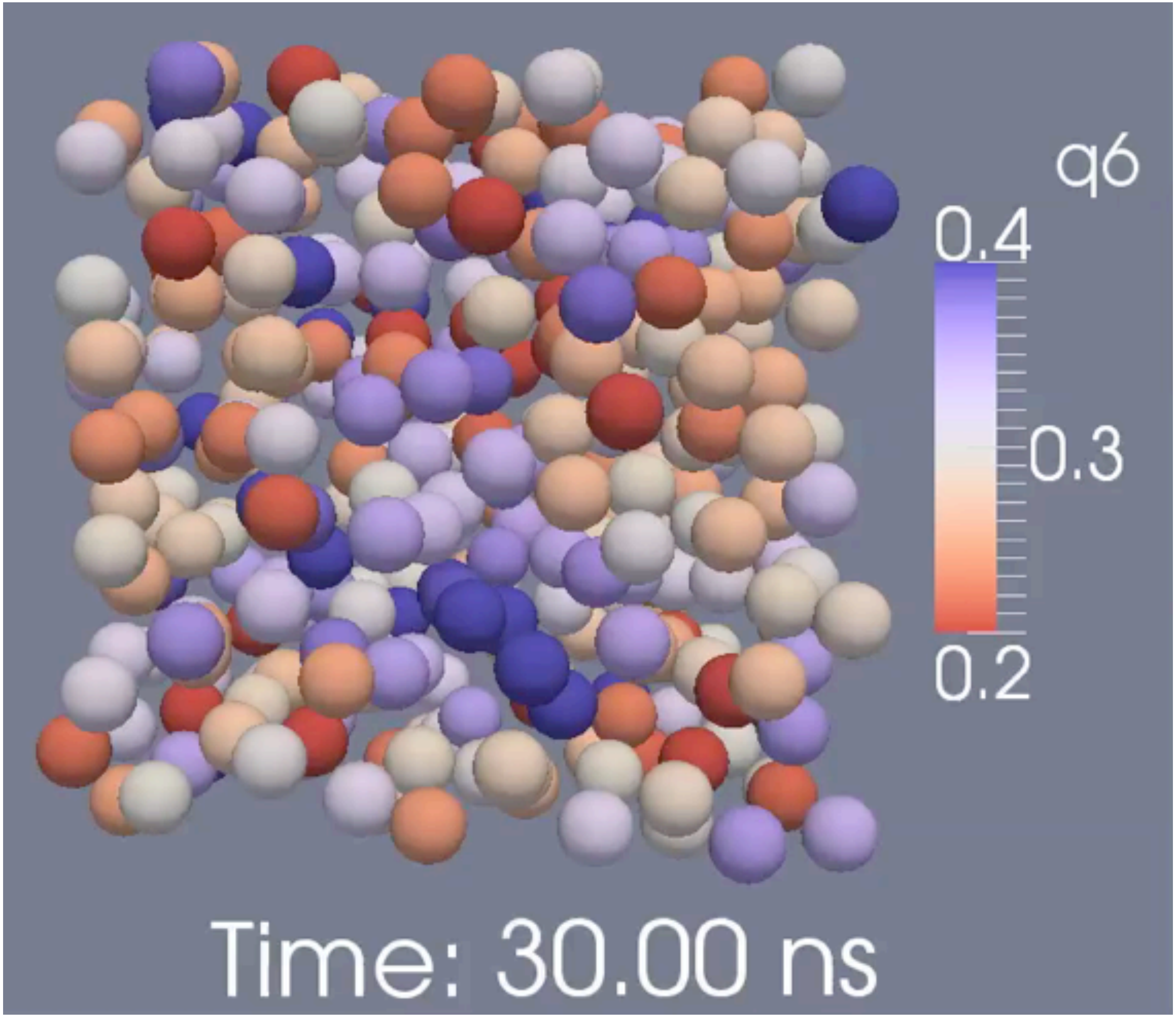
FROM THE VERY SMALL TO THE VERY LARGE

~1/100 SECOND → ~100 DAYS



100x60x60x24x100 = 1,000,000,000....9 orders of magnitude !

Preis/HES/Schneider (2011 PNAS, May 2011 Physics World)


q6
0.4
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0.2
Time: 30.00 ns

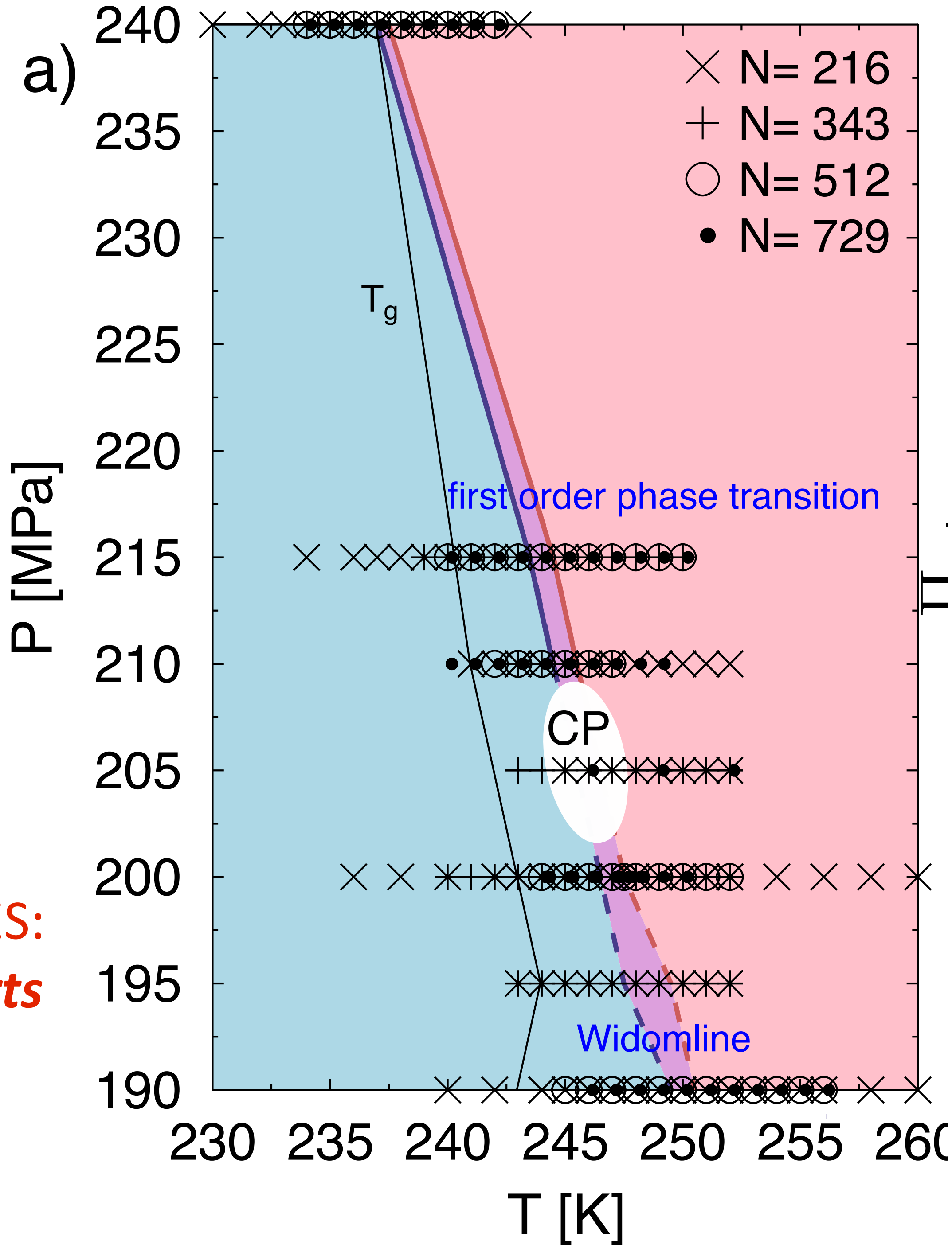
+

350 State Points analyzed
4 system sizes

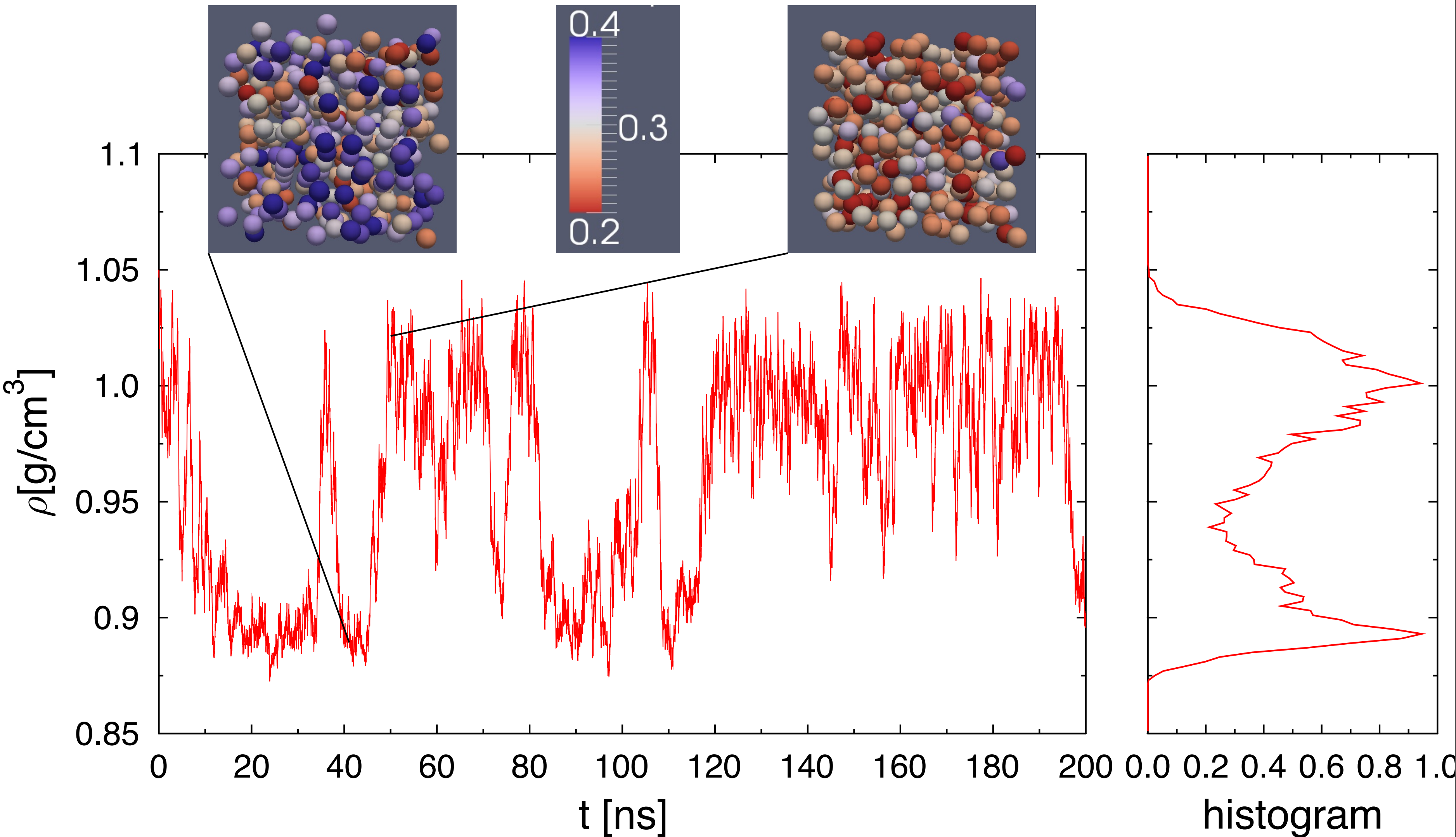
both sides of Widom line

both sides of LLPT line

Kesselring, Franzese, Buldyrev, Herrmann,HES: ***Nature Scientific Reports*** 2012; ***J. Chem. Phys.*** 2013



water: ***time dep. for 1 state point near ph. trans. line:***



Did Ehrenfest contribute to economics?

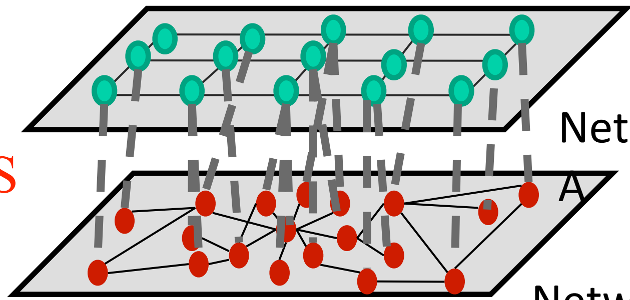
YES, says Jan Tinbergen!

Between 1921 and 1925, Tinbergen studied mathematics and physics at the University of Leiden under Paul Ehrenfest. During those years at Leiden he had numerous discussions with Ehrenfest, Kamerlingh Onnes, Hendrik Lorentz, Pieter Zeeman, and Albert Einstein.

In 1929 he defended his PhD thesis titled "Minimumproblemen in de natuurkunde en de economie" (Minimisation problems in Physics and Economics). This topic was suggested by Ehrenfest and allowed Tinbergen to combine his interests in mathematics, physics, economics and politics. Diego Garlaschelli biosketch

Critical Breakdown Threshold for 2 Interdependent Networks

Failure in network A
causes failure in network B
causes further failure in network A …..CASCADES



What are the critical breakdown thresholds for such interdependent networks?
What is size of cascade failures?

FURTHER EXAMPLES OF INTERDEPENDENT NETWORKS:

- *Economy*: Networks of banks, insurance companies, and firms which interact and depend on each other.

- *Physiology*: The human body is composed of inter-dependent networks (hip!)

- *Biology*: A specific cellular function is performed by a network of interacting proteins, which depend on other networks

Buldyrev, Parshani, Paul, Stanley, Havlin, Nature, **464**, 1025 (2010)