

"Quantifying Fluctuations on Time Scales from **Milliseconds** to **Years**, using concepts of critical phenomena" [HES@bu.edu]

How to understand “switching w/o switches”

work by: Podobnik, Gabaix, Preis, Vodenska, Pammolli, Riccaboni, Mantegna, Havlin, Buldyrev, Schneider, Gopikrishnan, Plerou, Liu, Cizeau, Wang, Yamasaki, Rosenow, Amaral, Petersen, Levy, Ivanov, Matia, Weber, Chessa, Lee, Meyer, Carbone, Ben-Jacob, Kenett, Moat, Fu & YOU?

Buldyrev, Pammolli, Riccaboni, & HES: “Rise & Fall of Business Firms” (2016).

We fail to understand bubbles: Some think the few big bubbles are what we must understand & control (Isaac Newton)

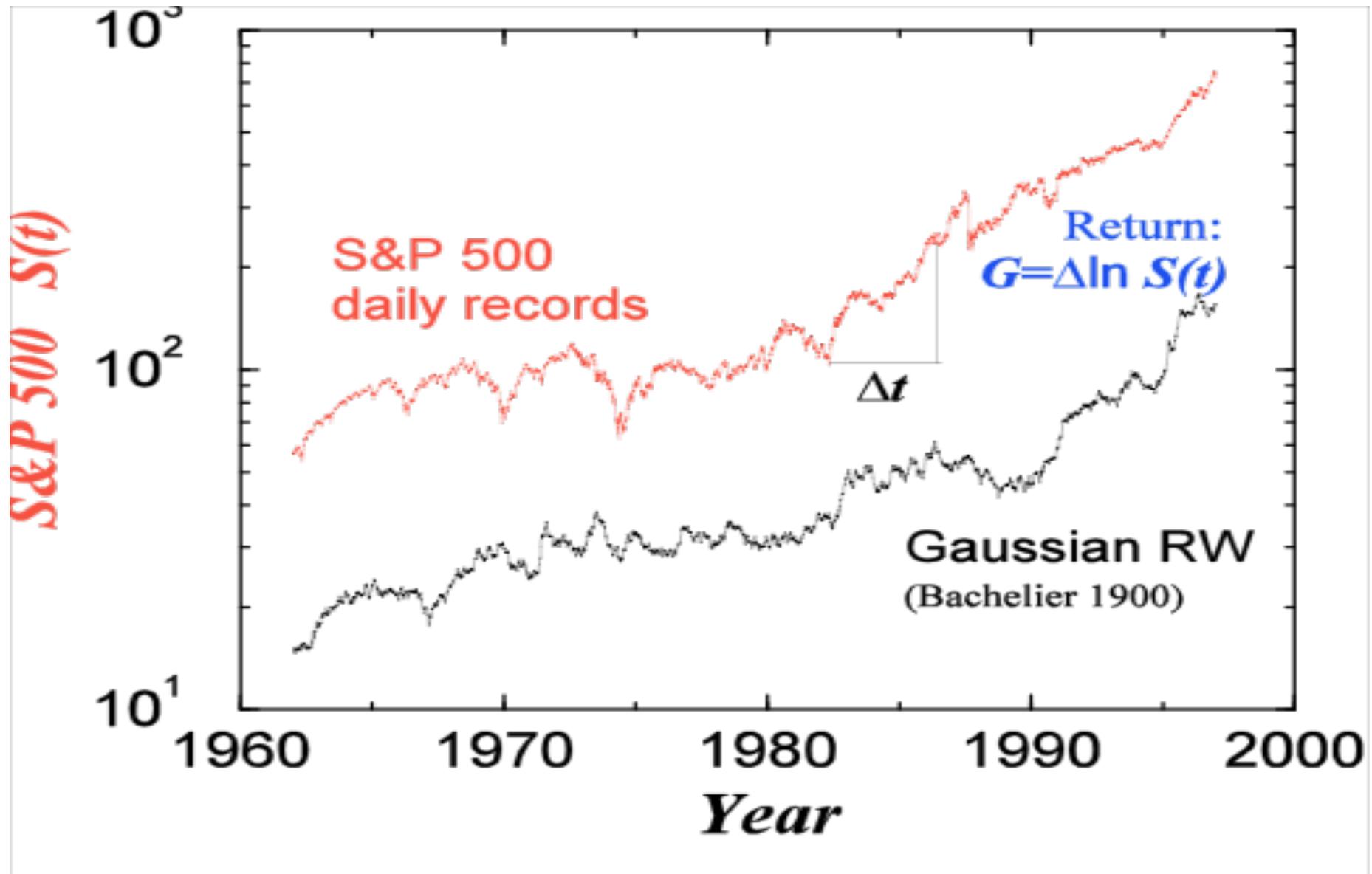
INTERDEPENDENT (“COUPLED”) networks of traders

Microtrend switching and bubbles of ****ALL**** size/time scales

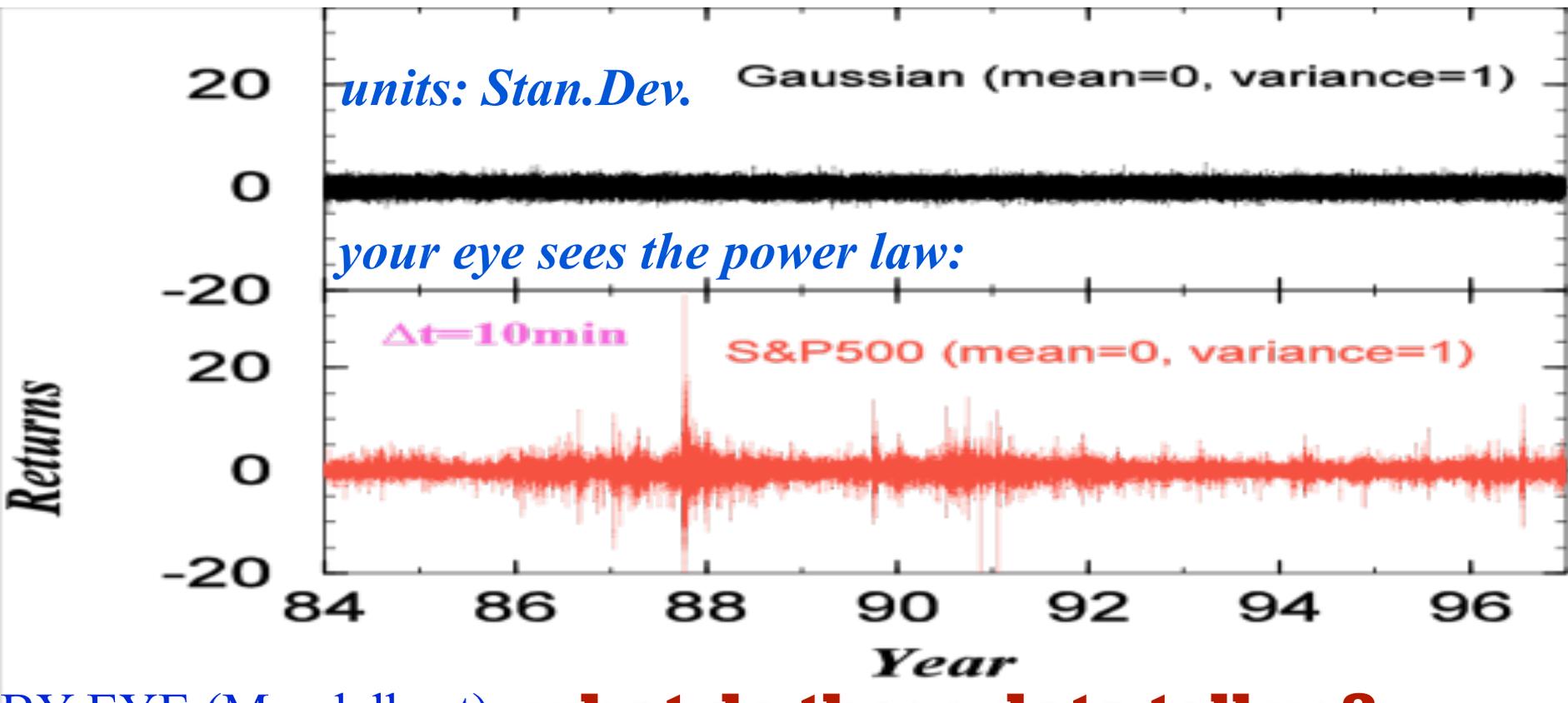
We **cannot** predict future value, but we **can** quantify risk -- like earthquakes, tornados, heart attacks, ...

Take-Home Message = “Data Driven Discovery” (DDD)₁ reveals **finance fluctuations exemplify “switching w/o switches”**

EXAMPLE: complex interacting Networks: S&P 500 index



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



BY EYE (Mandelbrot)--**what do these data tell us?**

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

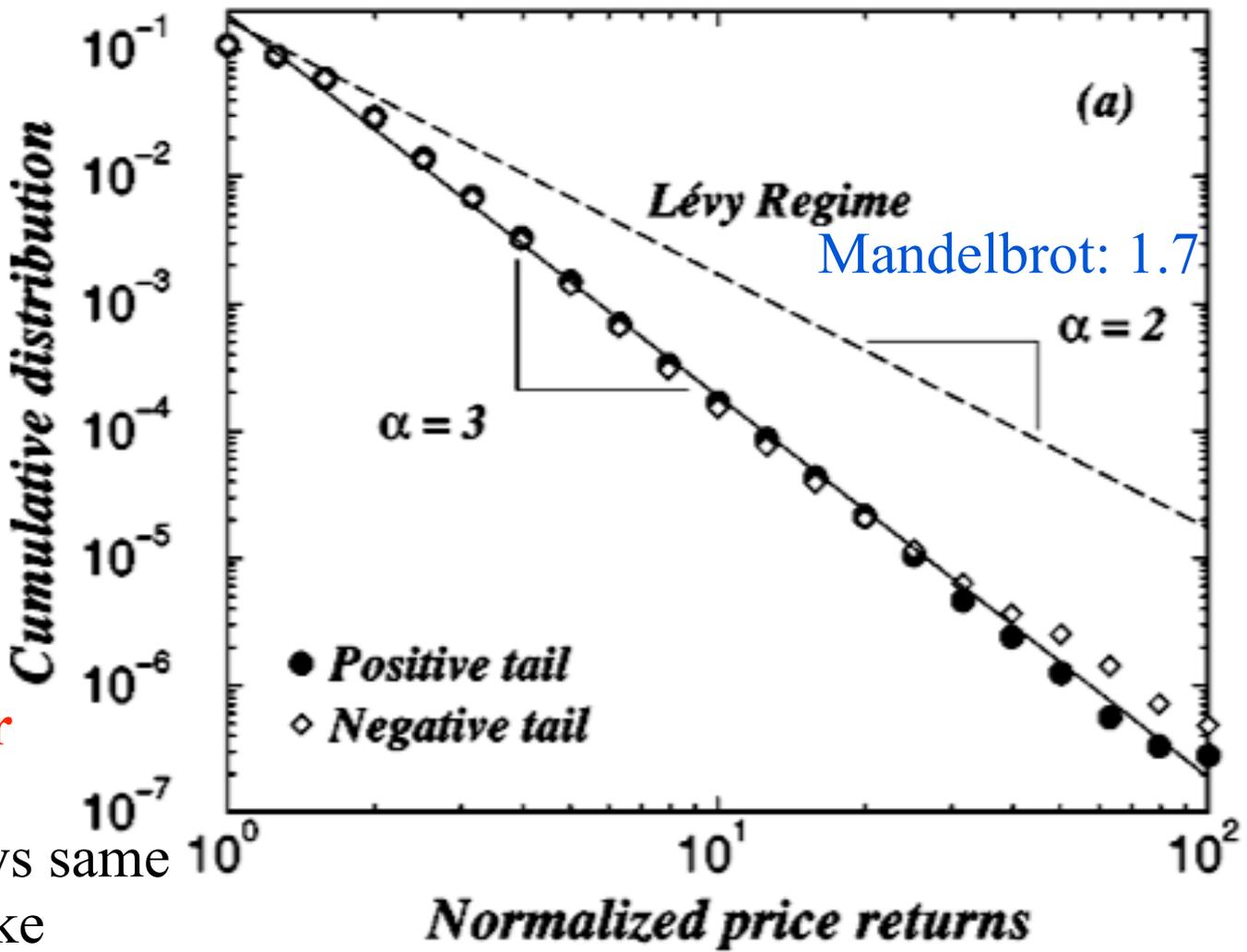
Large events cluster (like earthquakes) (also known **qualitatively**)

"Aftershocks" Omori-correlated (Lillo/Mantegna 03; Petersen/Havlin/HES 07)

"Aftershocks of each aftershock" Omori-correlated: long-range power law

(BY EYE) **WHAT DO THESE DATA TELL US?** “*Inverse cubic law*” holds over 6 orders of magnitude on y-axis (8 for pdf: inverse quartic)

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



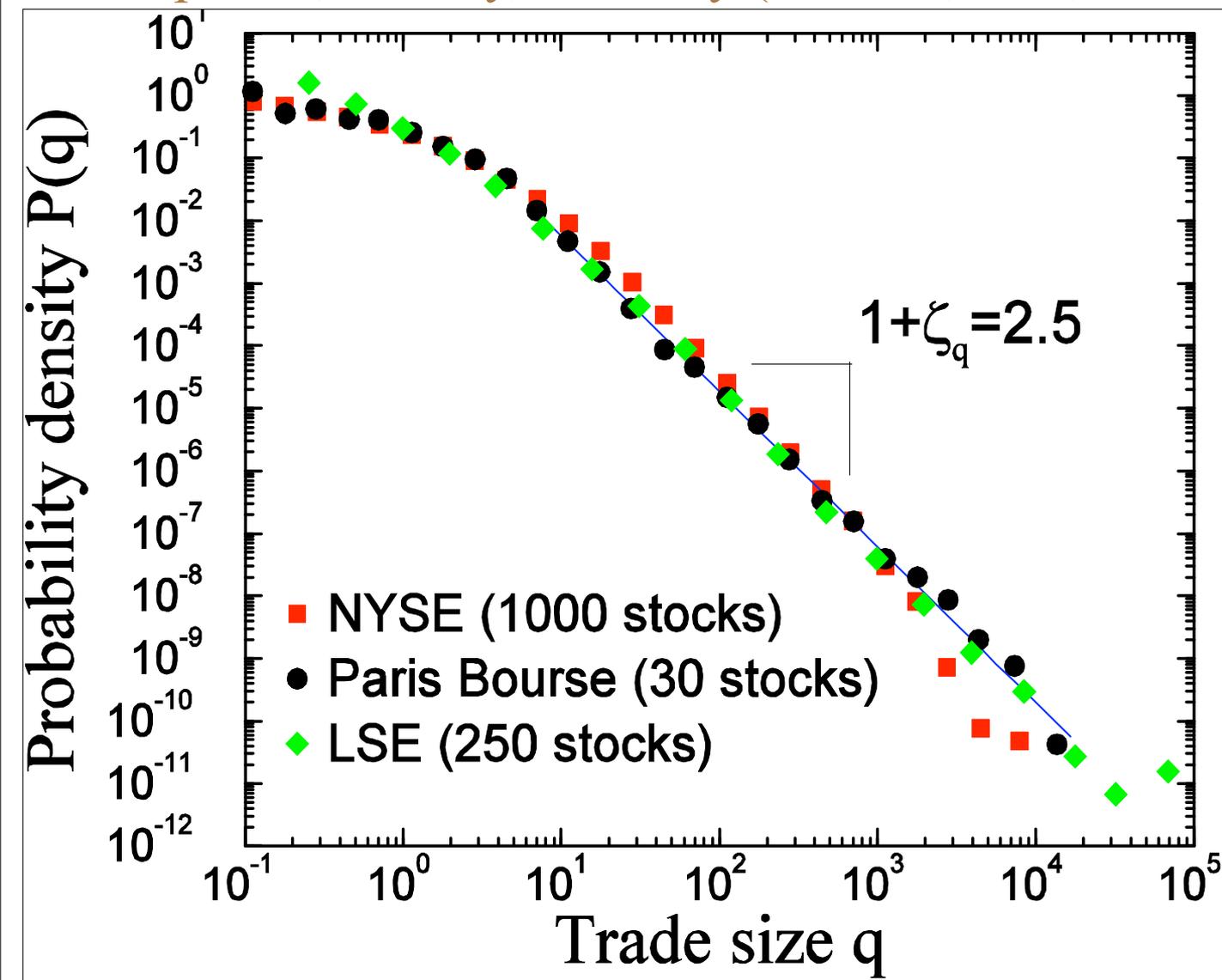
Gutenberg-Richter earthquake law: mag = 7 quake obeys same law as mag = 1 quake

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

Gopikrishnan, Plerou, HES

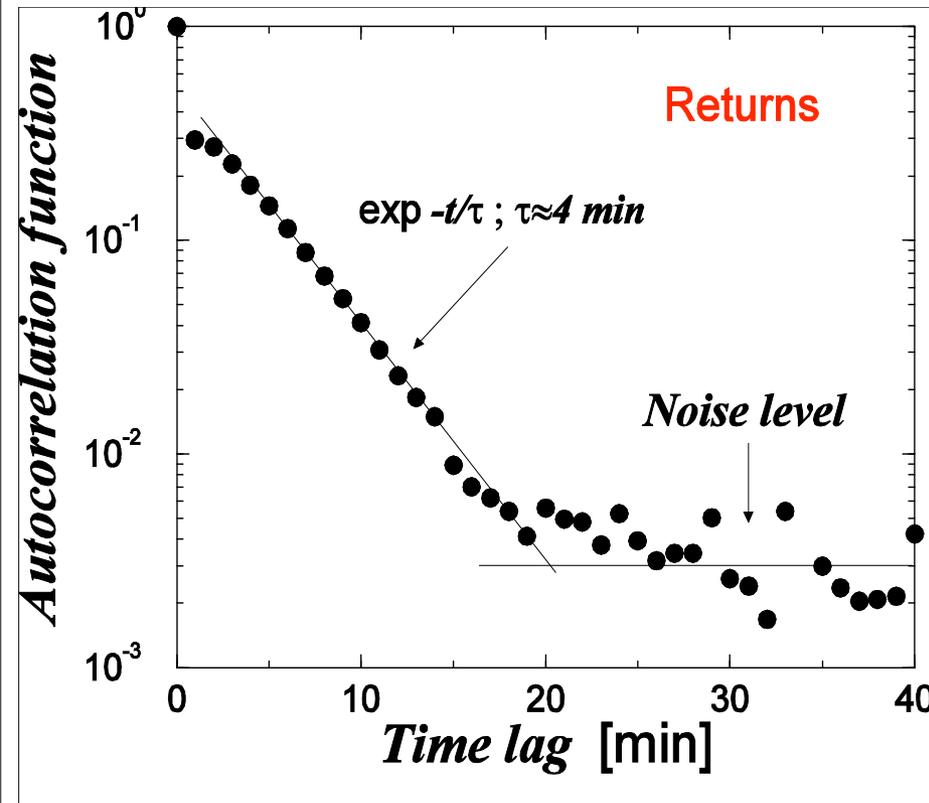
TEST: if interacting system of subunits, should be “*universality*”

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

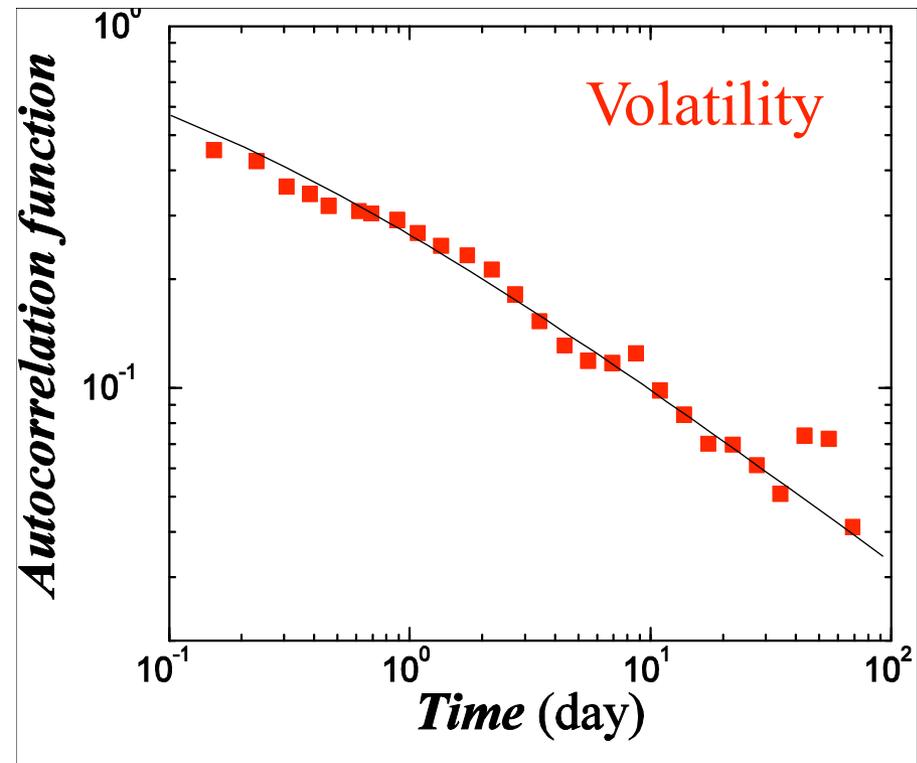


Physicists look for Correlations in Complex Systems

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



$$\leftarrow R_t = \text{sgn}(R_t) \quad |R_t|$$



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

“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 (news). J depends on the two stocks, and H depends on the stock. Both can change with time.

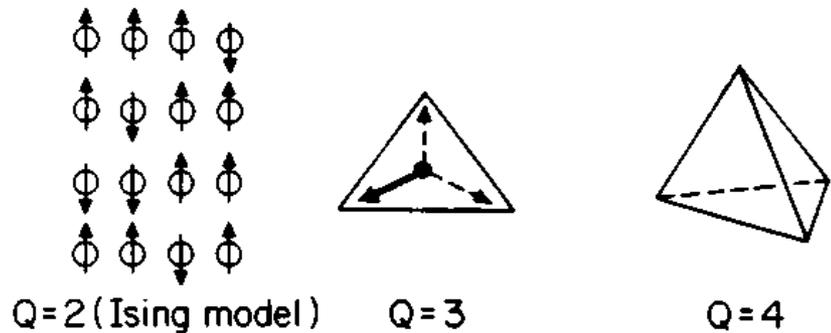
(c) *modified Edwards-Anderson “spin glass”* with TIME-dependent LONG-range interactions both signs

Possible models:

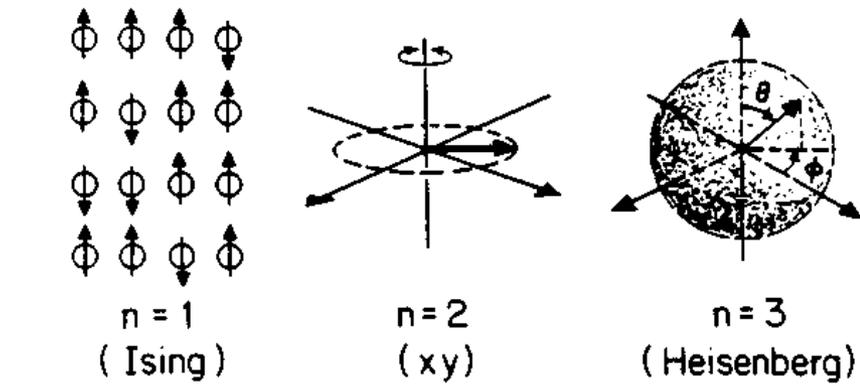
(a) Units can be in Q different DISCRETE states: “Potts Model” (Potts 1952).

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

(a) Potts Model:



(b) n -Vector model:



The case $H=0$ (no news): Ising model?



text

The case $H=0$ (no news): Ising model?



Can a law describe bubbles and crashes in financial markets?

Tobias Preis^{1,2} and H. Eugene Stanley¹

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

Physics World, May 2011

DETAILS IN:

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

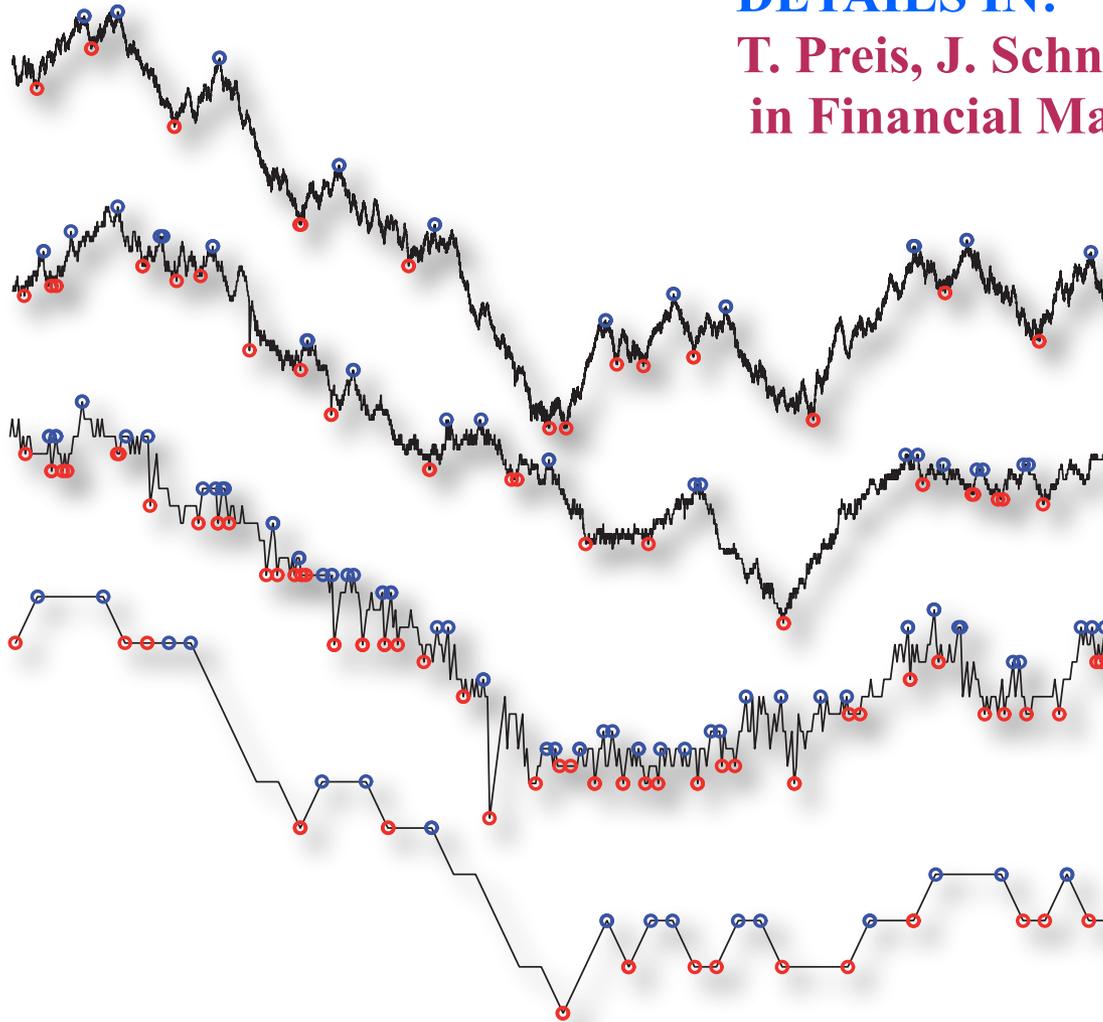
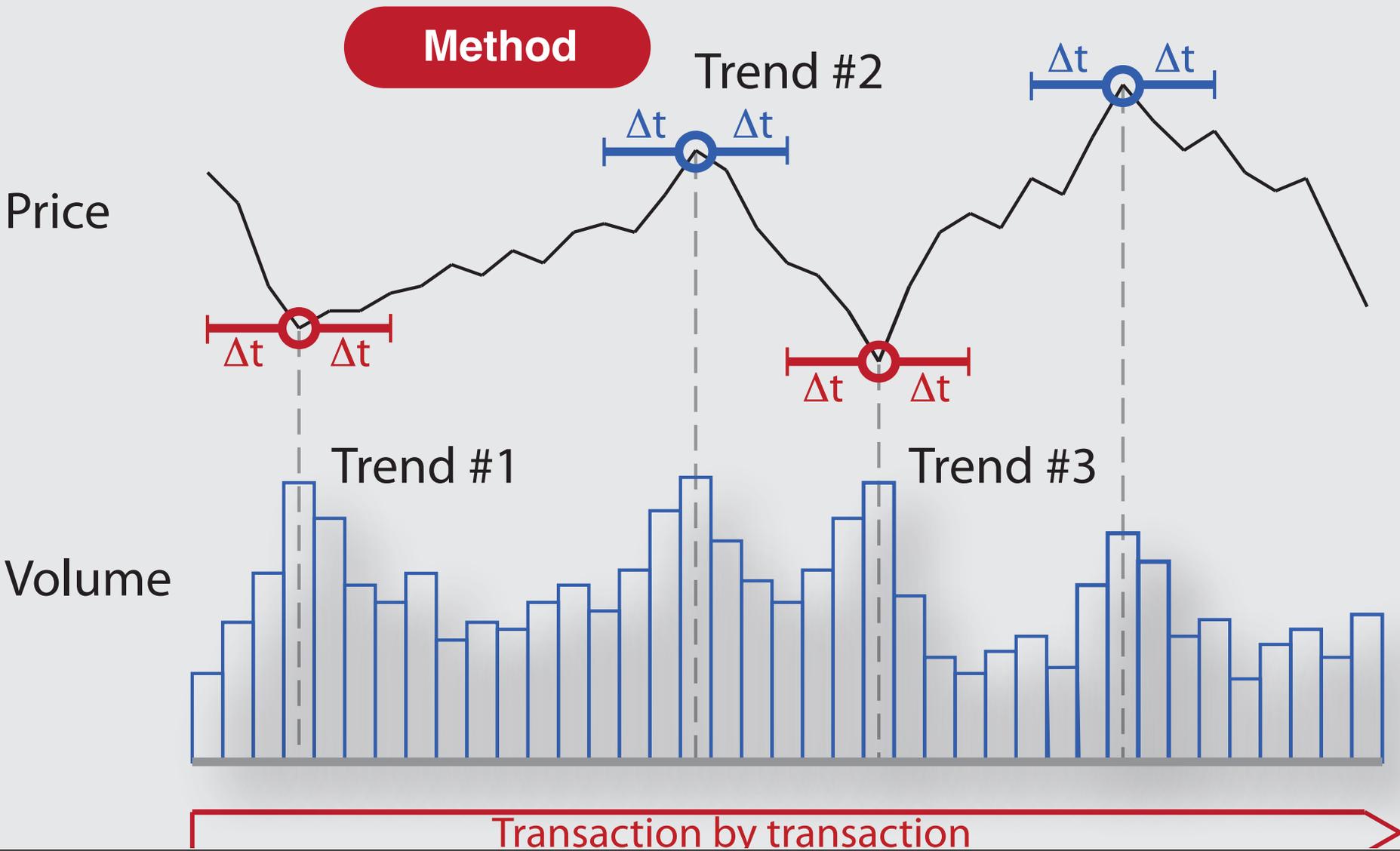


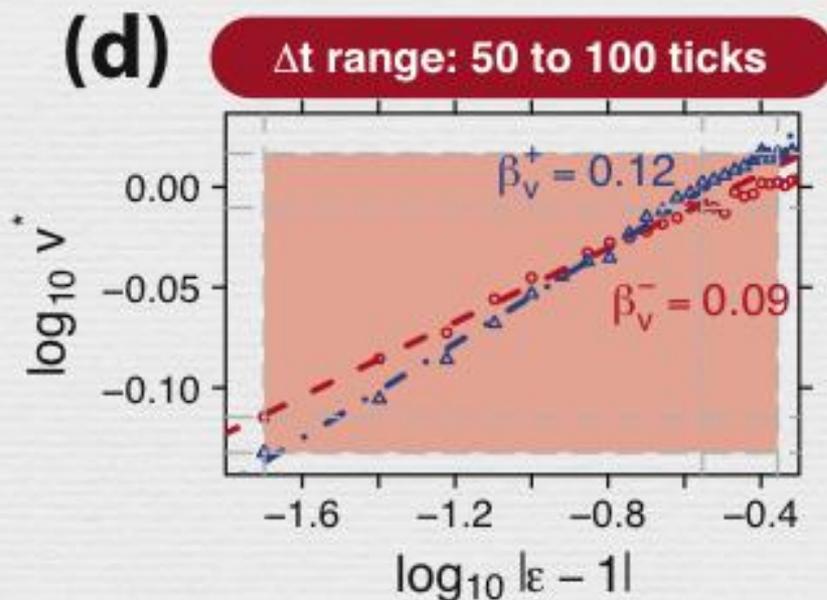
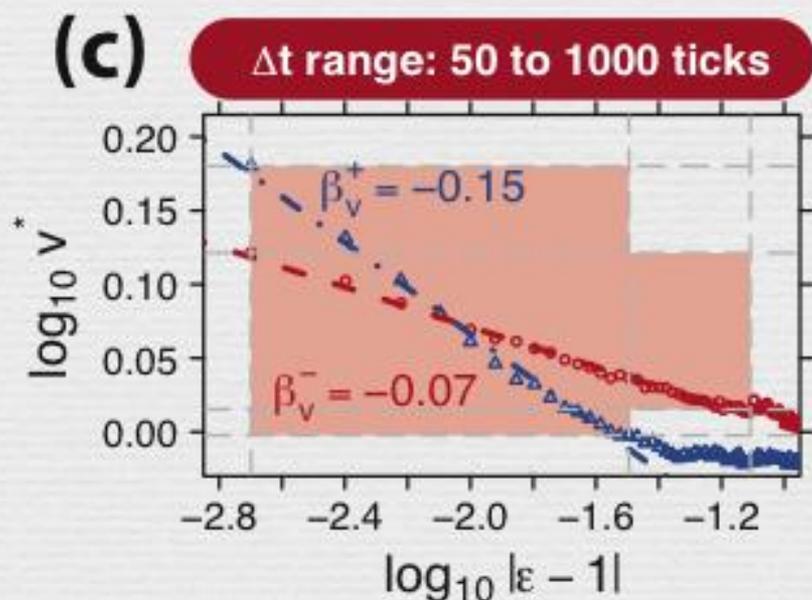
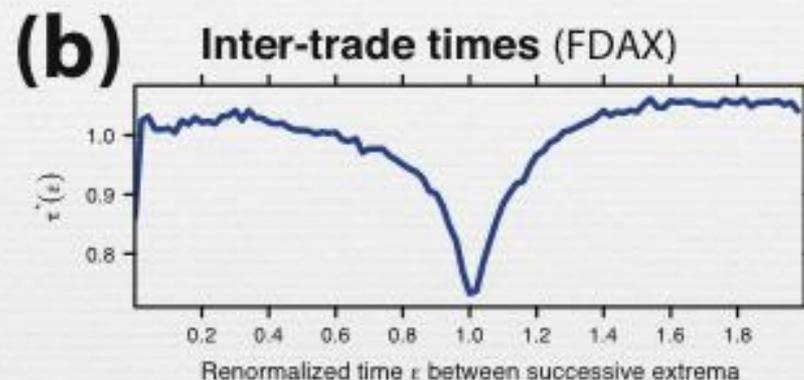
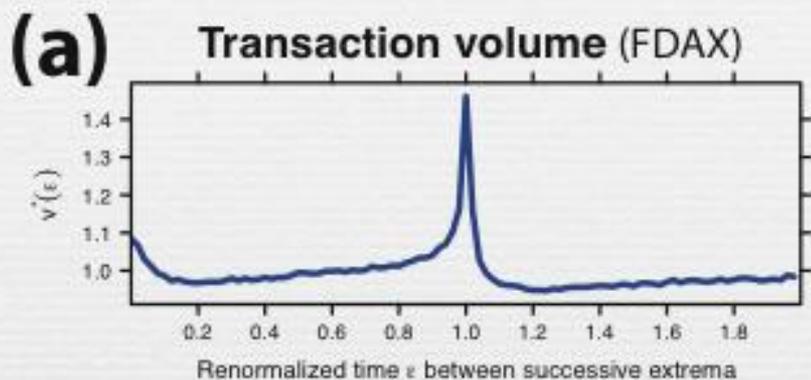
Figure 1 | Scale-free behavior of financial market fluctuations. Financial market time series feature identical properties on very different time scales. All four curves are subsets of a 14 million transactions dataset taken from a German DAX future time series. The price curves cover time periods of 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 analyze? A: Preis/Stanley PNAS 108,7674

(b) Determination of local price extrema ($\Delta t=3$ fixed)



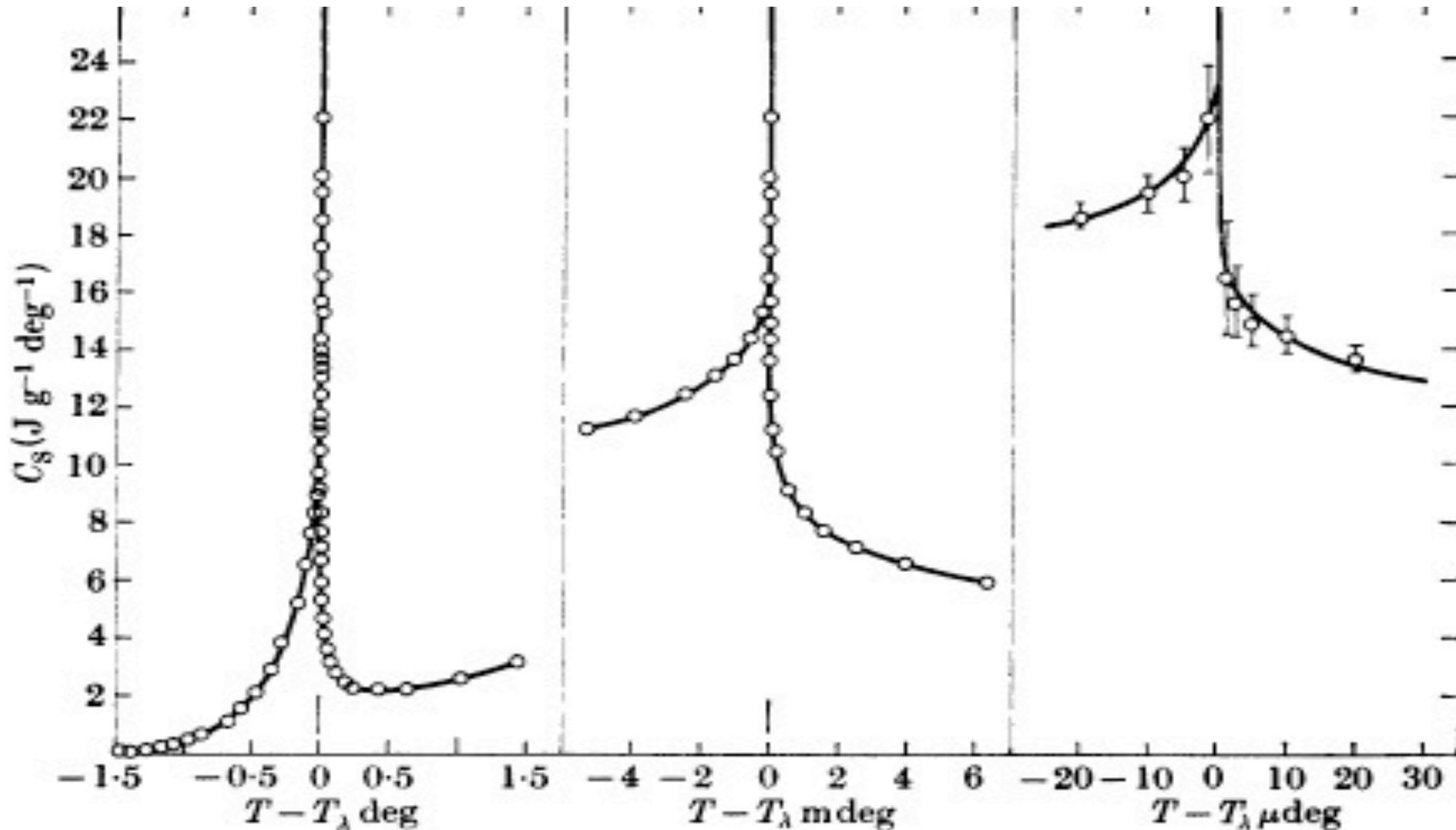
Quantities With Scale-Free Behavior



- Randomly reshuffling confirms our findings.

SCALE FREE SPECIFIC HEAT NEAR HELIUM SWITCH POINT

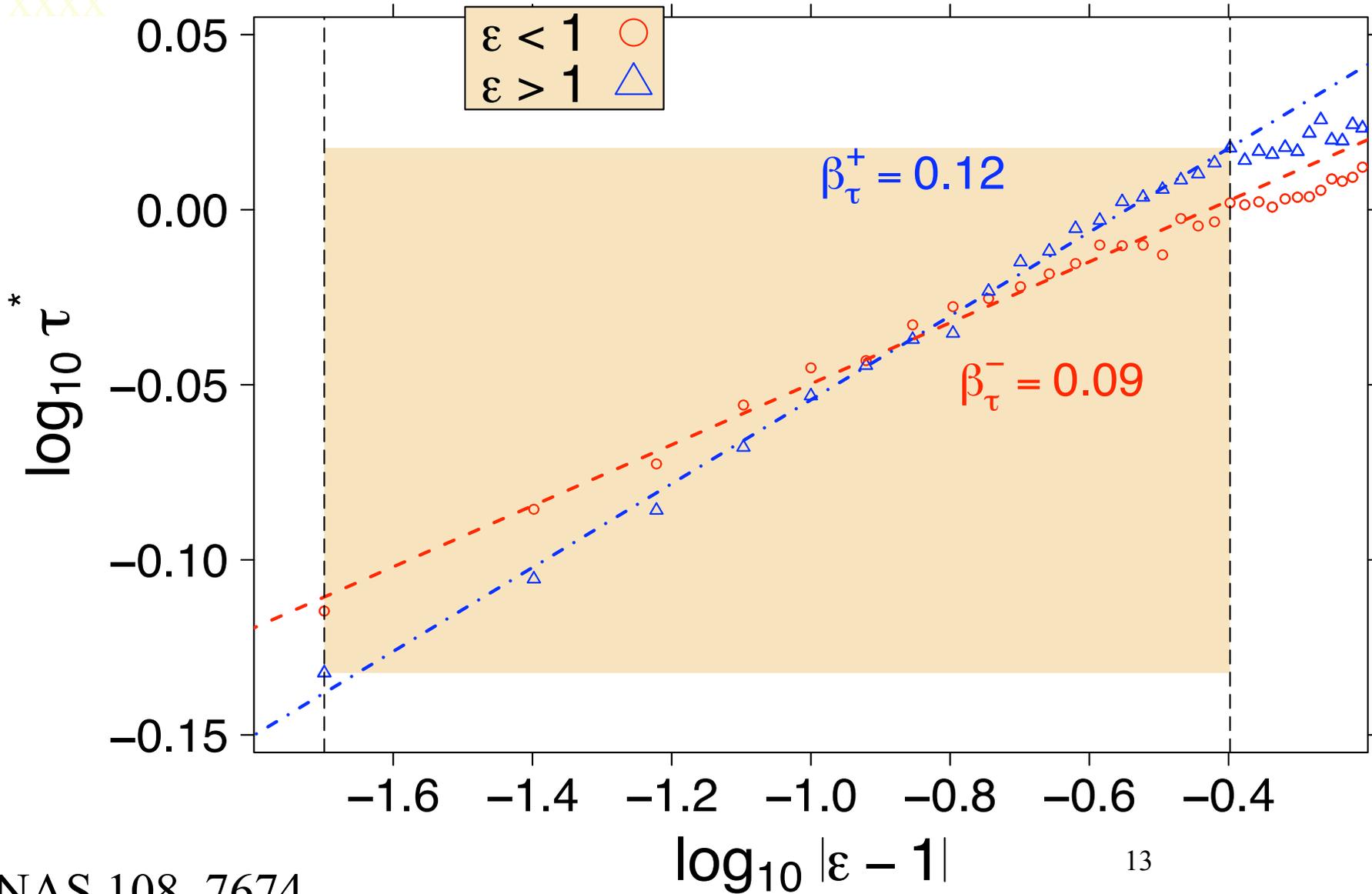
Note: Same FUNCTION for 3 different scales: 6 orders of magnitude!!!



Q: Can we **quantify this dip** in intertrade waiting time?

A: Evidence for a mathematical (power law) **singularity**

(a)

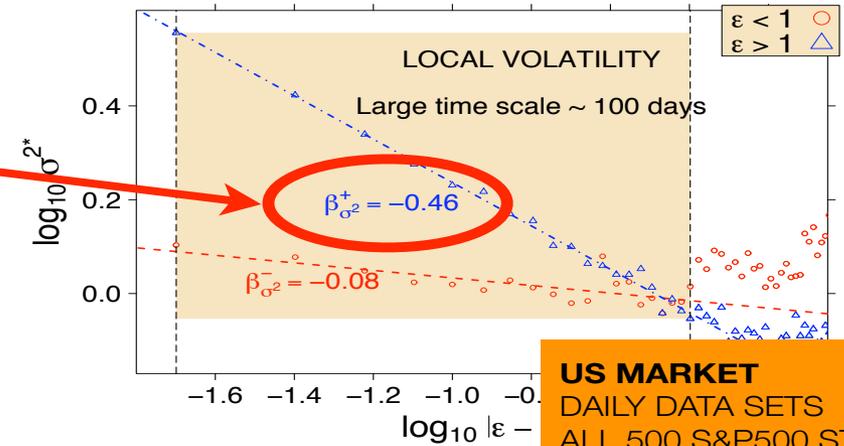
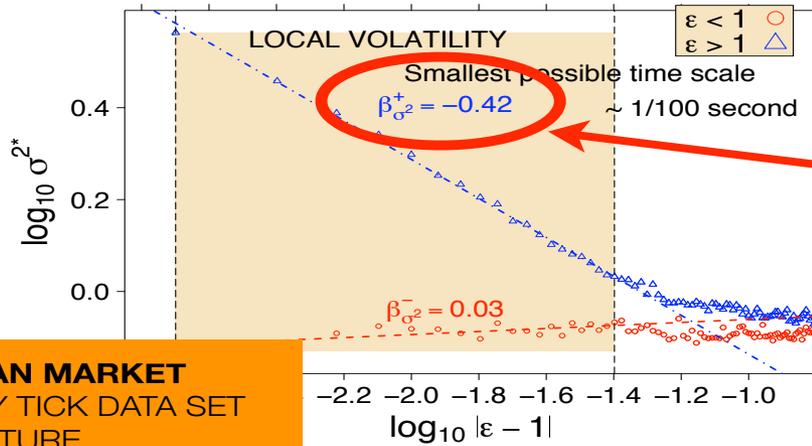


PNAS 108, 7674

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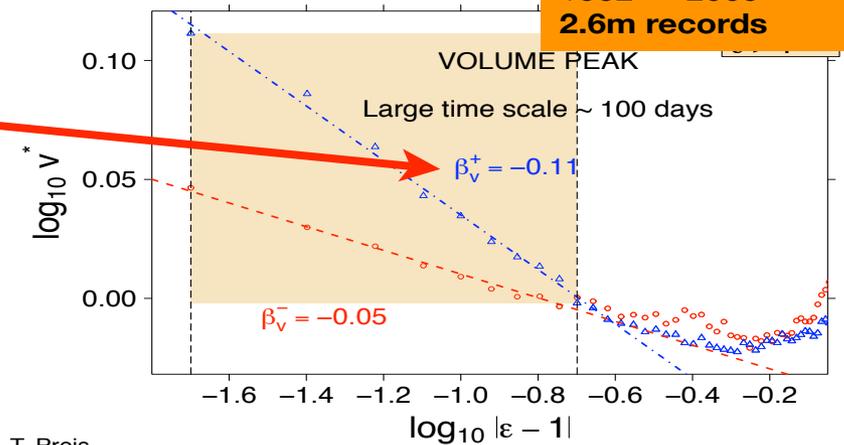
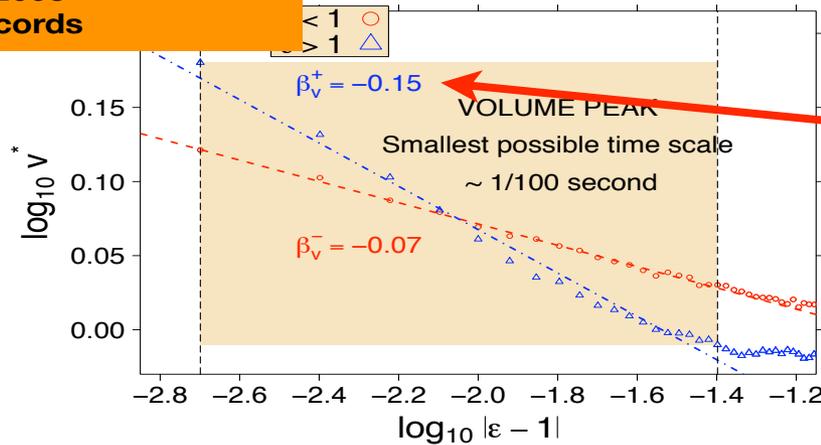
FROM THE VERY SMALL TO THE VERY LARGE

~1/100 SECOND → ~100 DAYS



GERMAN MARKET
TICK BY TICK DATA SET
DAX FUTURE
2007 — 2008
14m records

US MARKET
DAILY DATA SETS
ALL 500 S&P500 STOCK
1962 — 2009
2.6m records



T. Preis

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

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

A BIG BIG SURPRISE:

“Critical-point-like” phenomena near the “switch point” [like helium?]

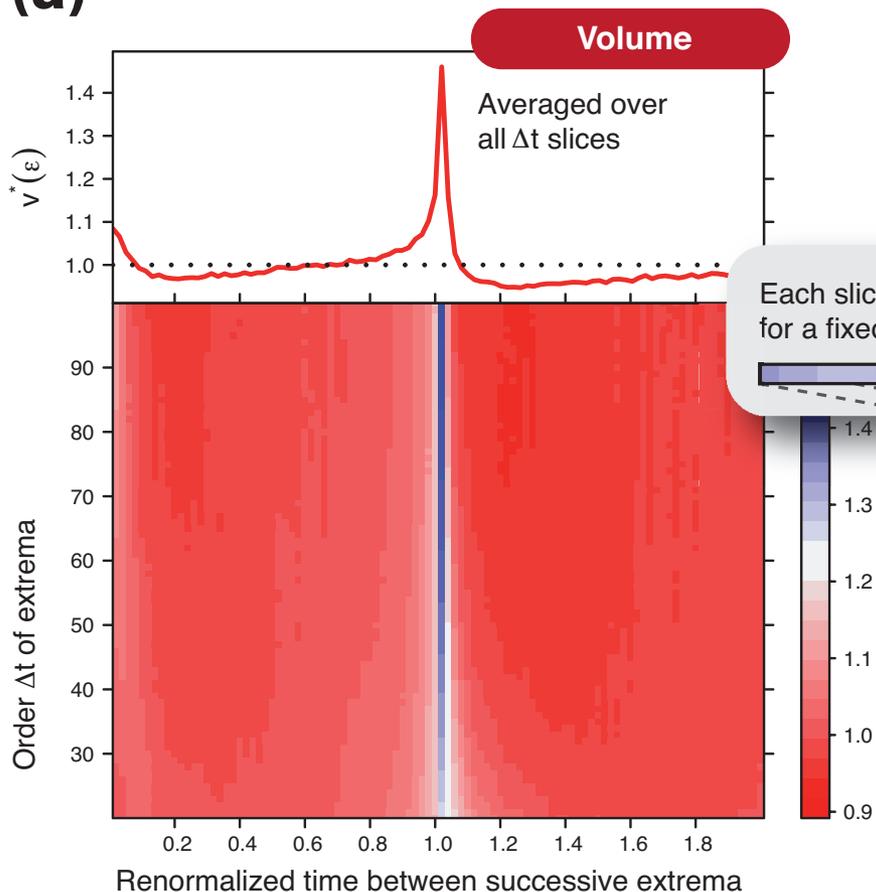
WHY? WHY? WHY? Preis/HES/Schneider (PNAS, Physics World)

(a) Network of traders---watching the identical screen???

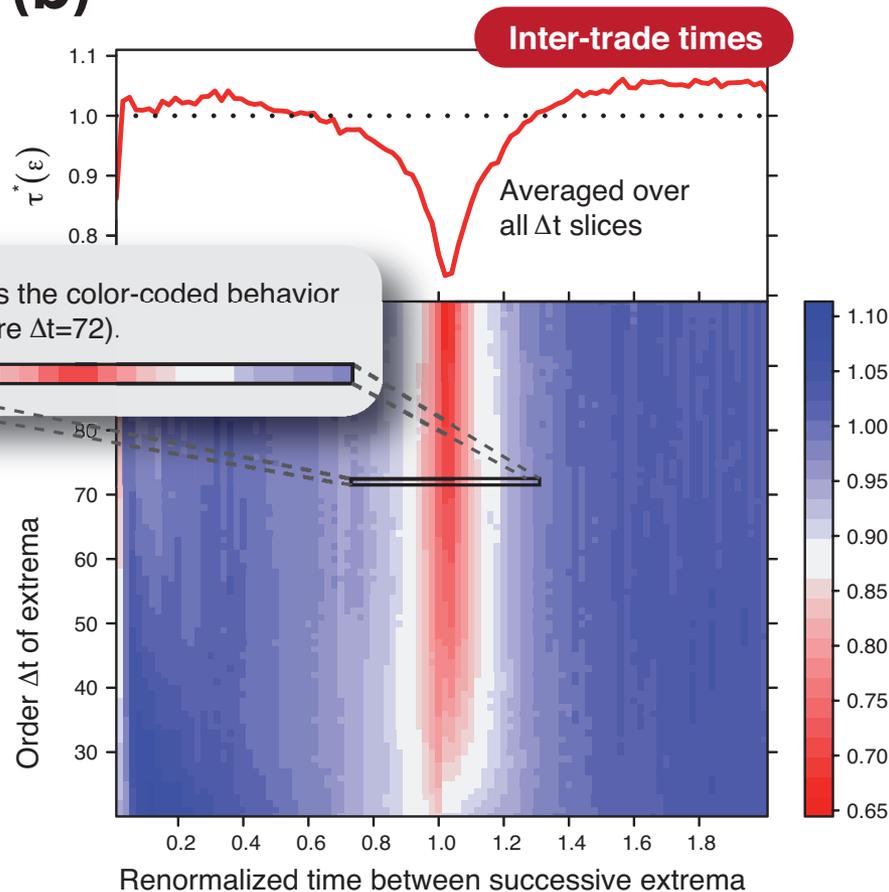
(b) “Scale-free PANIC” as trader worries to miss the switch???

(c) Other reason???

(a)



(b)



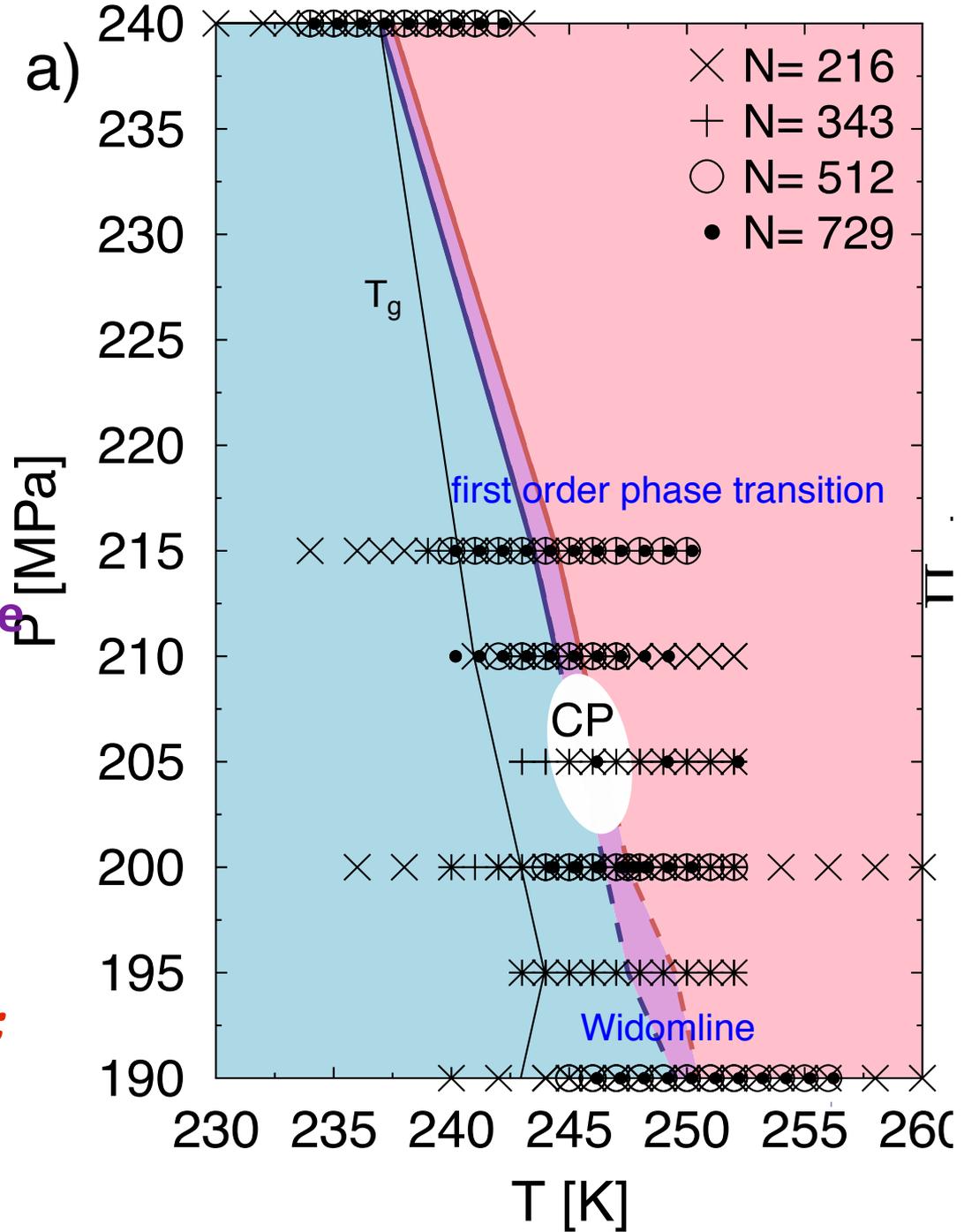
+

350 State Points
analyzed
4 system sizes

both sides of Widom
line

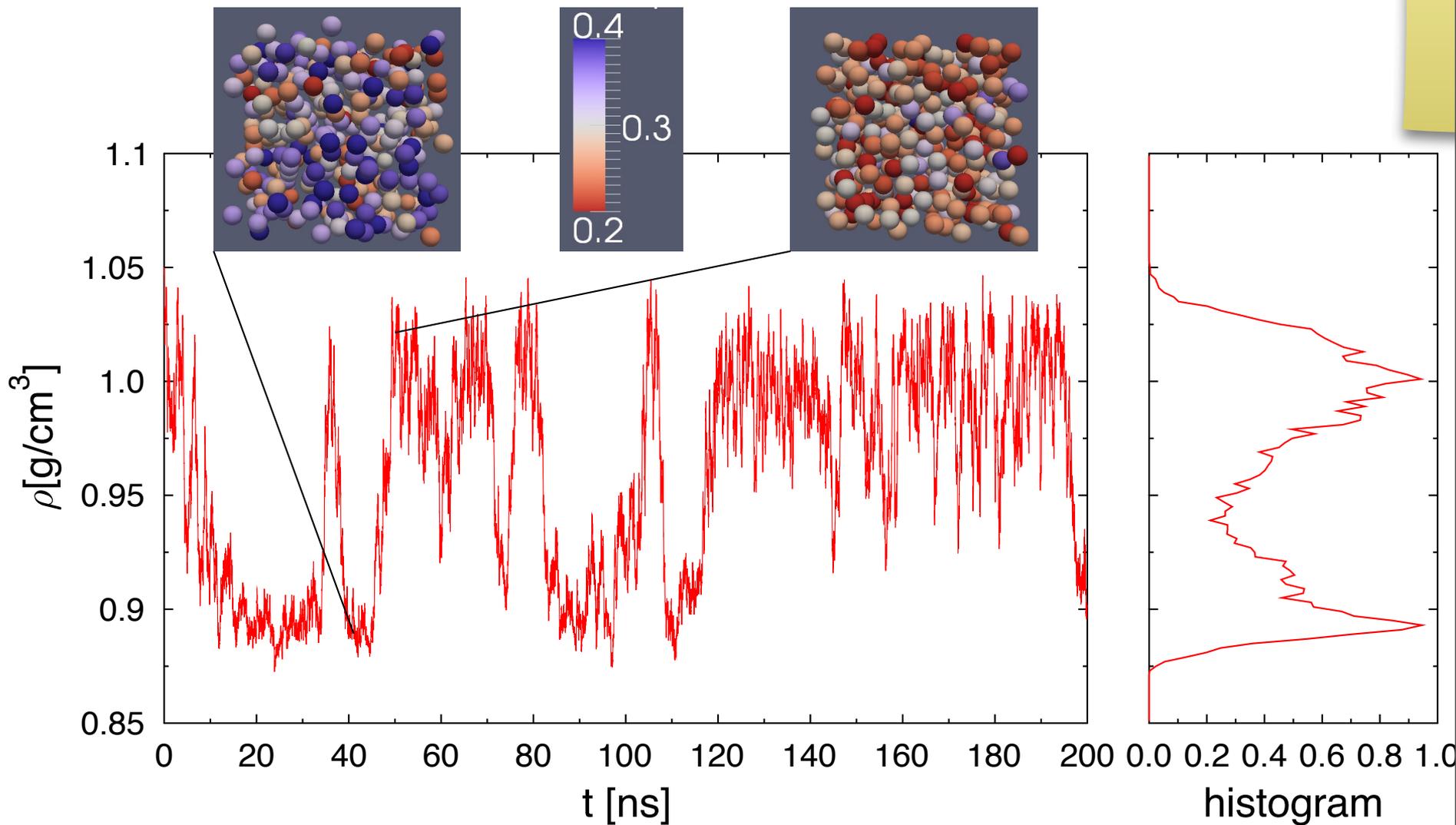
both sides of LLPT line

Kesselring, Lascaris,
Franzese, Buldyrev,
Herrmann, HES:
Nature Sci. Rep. 2012;
J. Chem. Phys. 2013

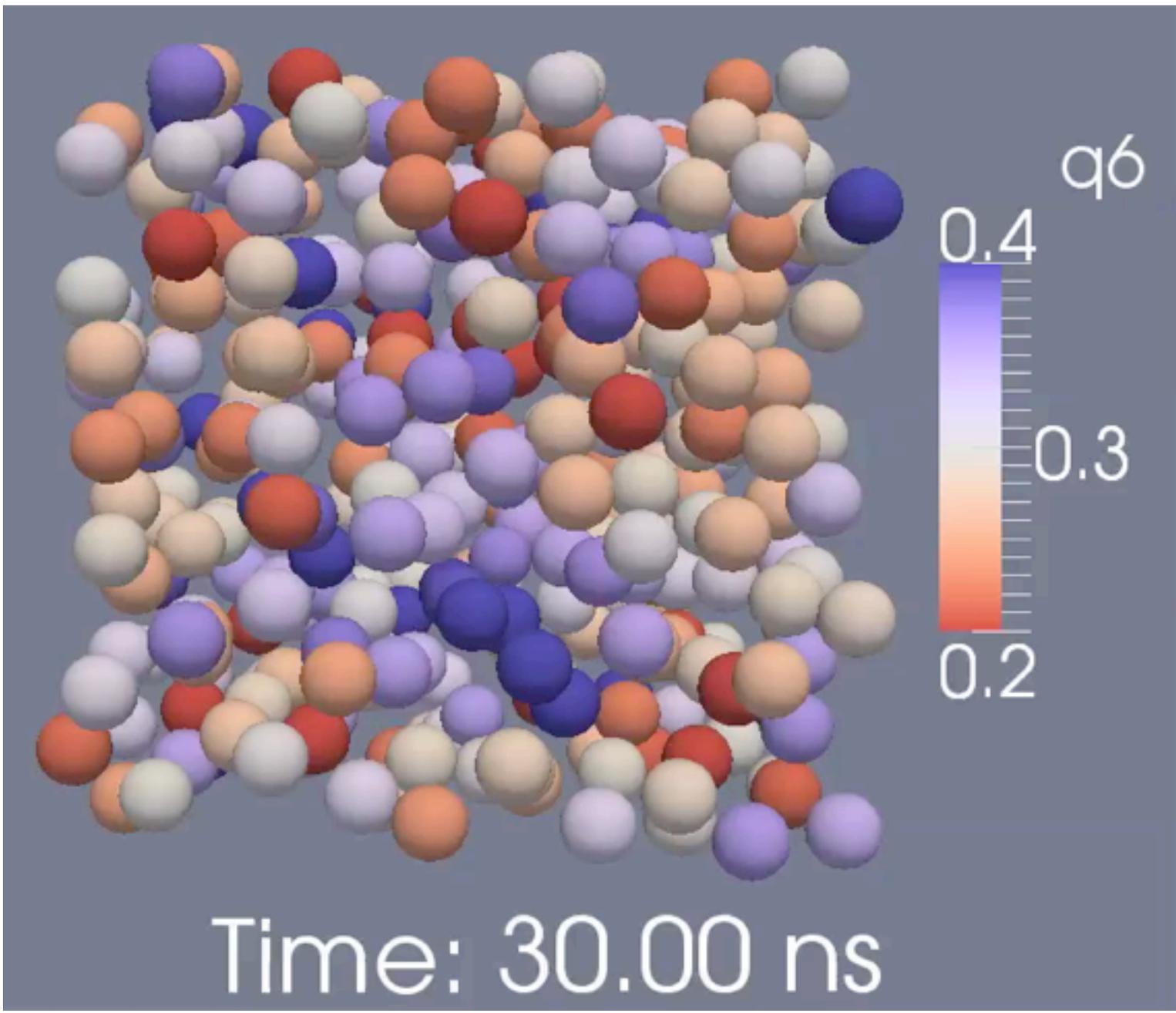


Test 21: *time dep. for 1 state point near ph. trans. line:*

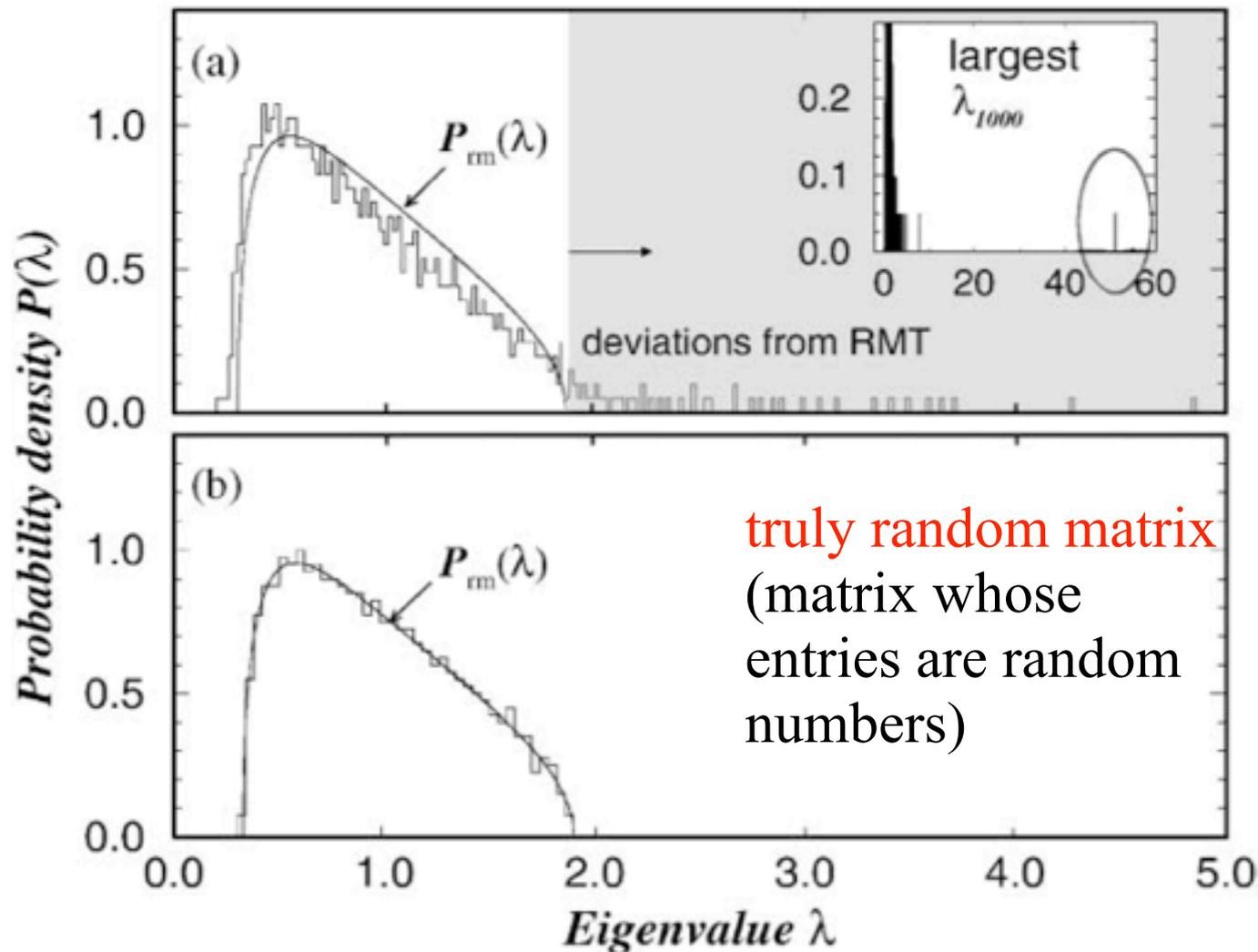
Kesselring, Lascaris, Franzese, Buldyrev, Herrmann, HES: Nature Sci.Rep.2012; JCP 2013







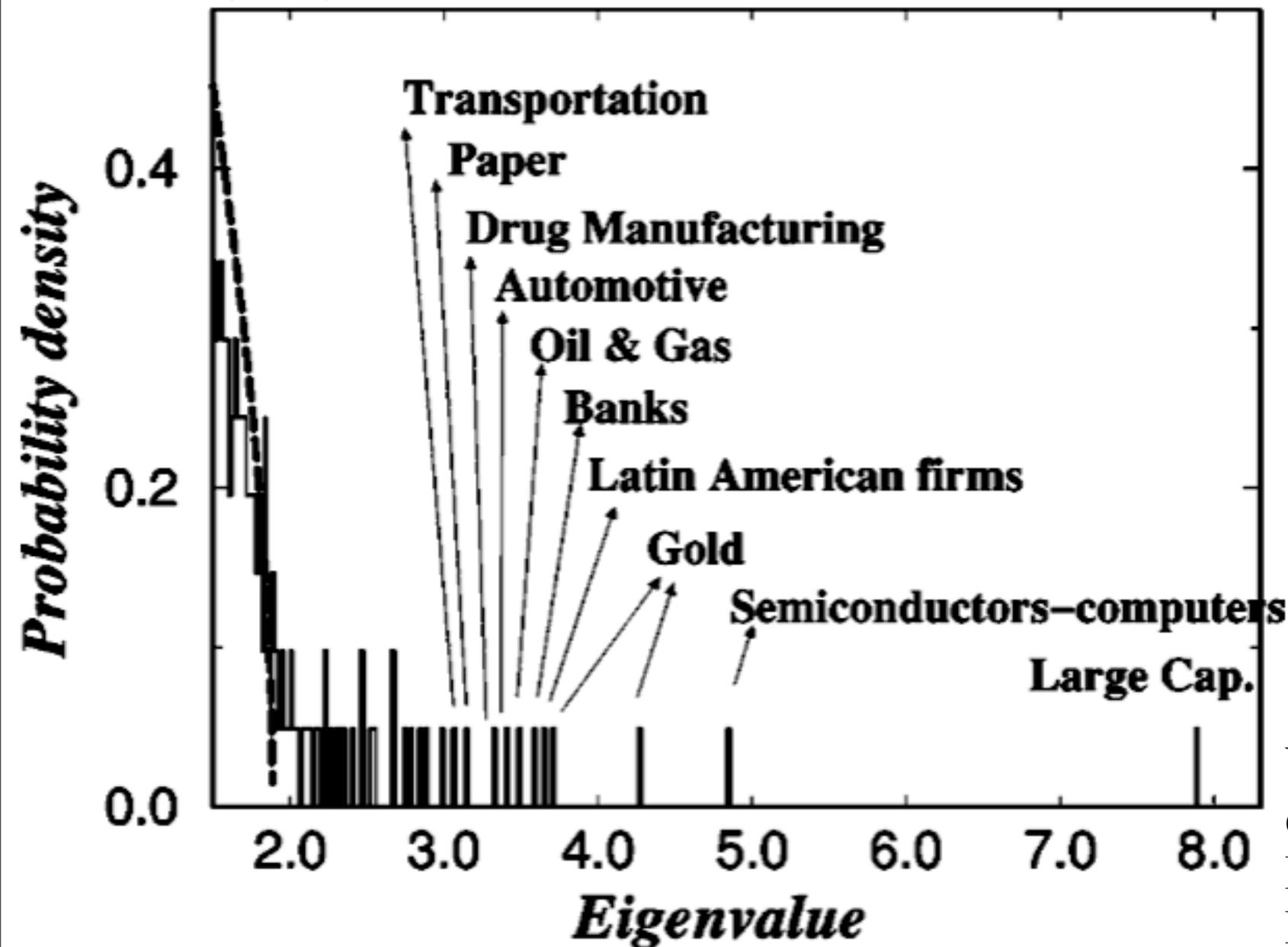
Question: How to recognize **true** from **apparent** return-return correlations?
 Answer (Wigner): Eigenvalue distribution of covariance matrix **VERSUS** that of a random distribution. 1000 TAQ stocks (hence 1000 eigenvalues)



Question:
 Which stocks **dominate** the eigenvectors corresponding to the 20 deviating eigenvalues?

Laloux et al;
 Plerou et al
 [PRL & PRE]

Question: Which stocks dominate the eigenvector corresponding to a “deviating” eigenvalue?



V. Plerou
et al. ,
PRL and
PRE

Can physicists contribute to economics?

- get an eco. partner...and **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 timid: e.g., Aggregate, ...
- try to relate the findings (ex: price, volume, intertrade times, volatility,...)
- Try to make a “**theory**” relating facts :)

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Dedication: GOOGLE & BIG DATA & HES@BU.EDU

THANK YOU

HES@BU.EDU

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