Trend Switching Phenomena in Financial Markets

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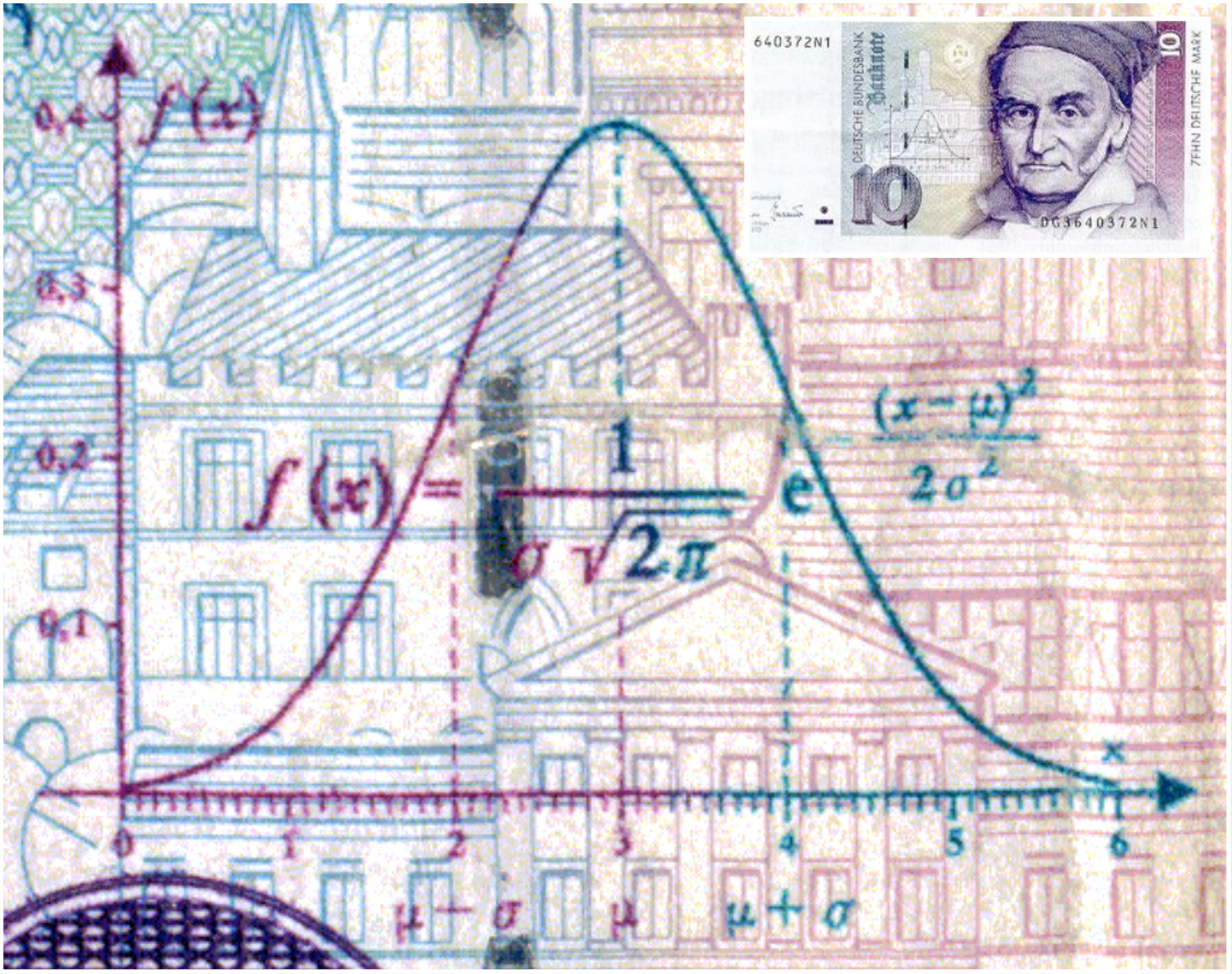

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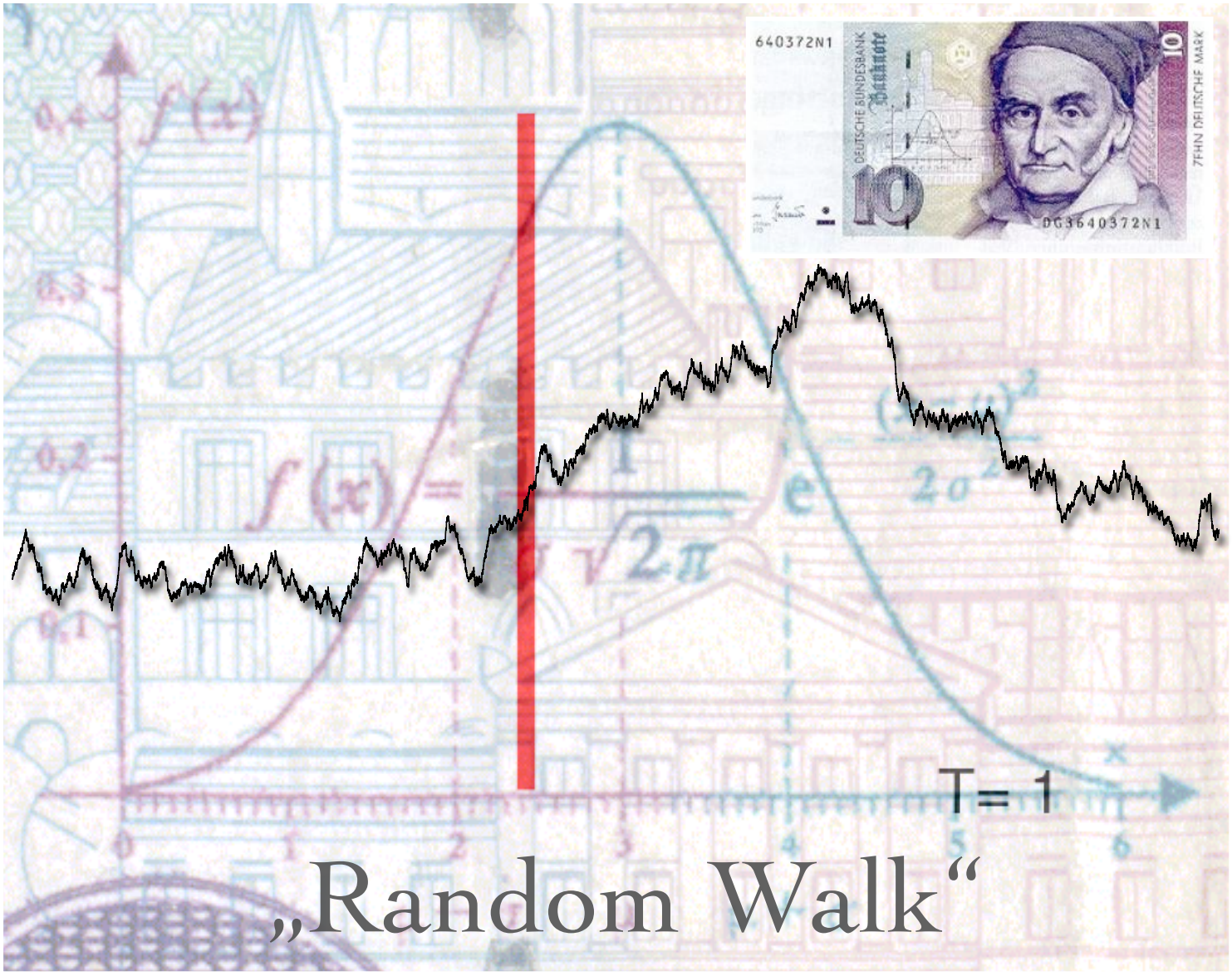

„Random Walk“

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Outline

(i) "Econostatics" vs. "Econodynamics"

(ii) Analysis of complex pattern-based correlations in high frequency financial market data.

(iii) Switching processes in financial markets.

(iv) Agent-based model reproducing empirical stylized facts based on an order book structure.

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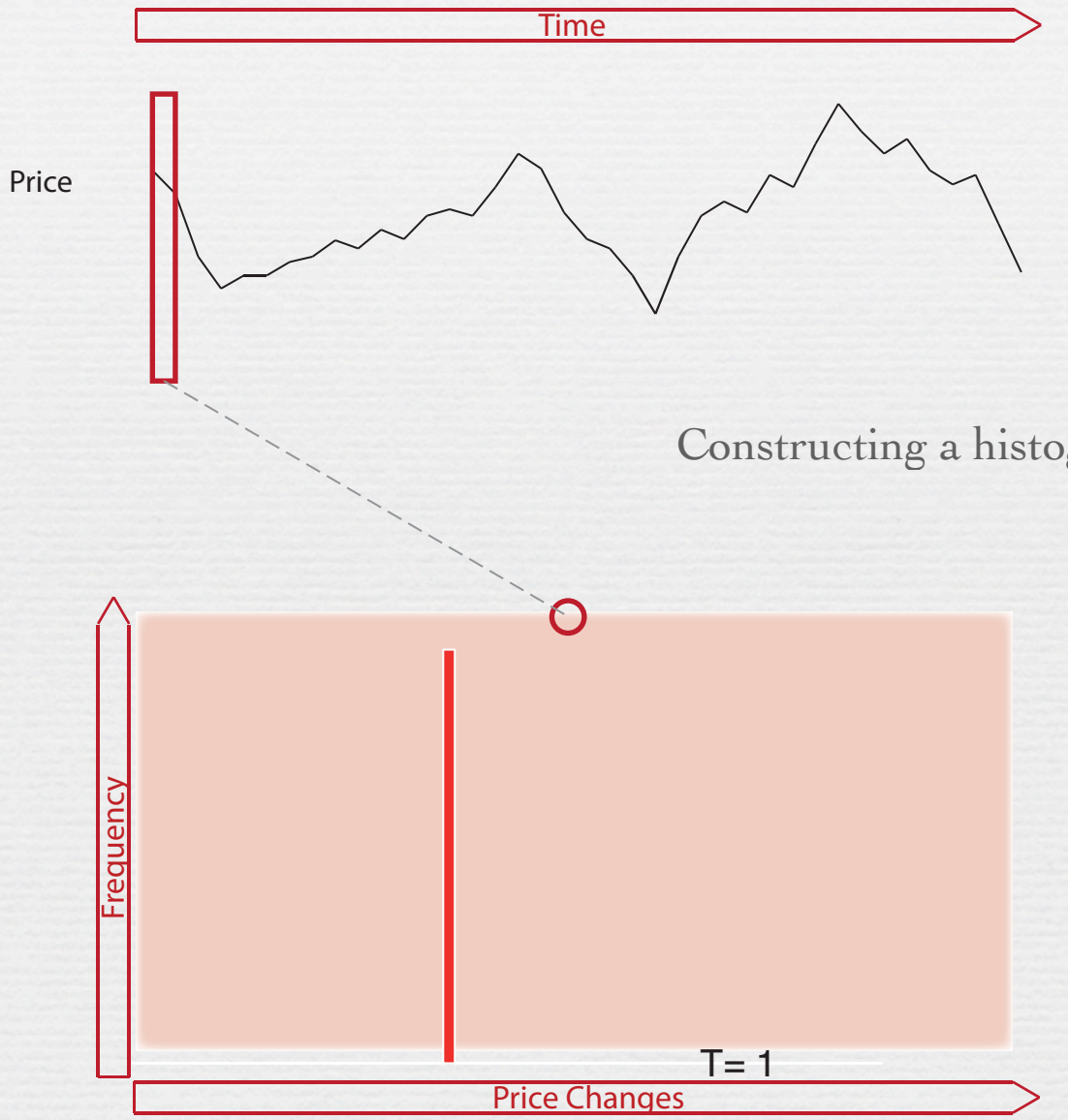
"Econostatics"



Constructing a histogram of price changes

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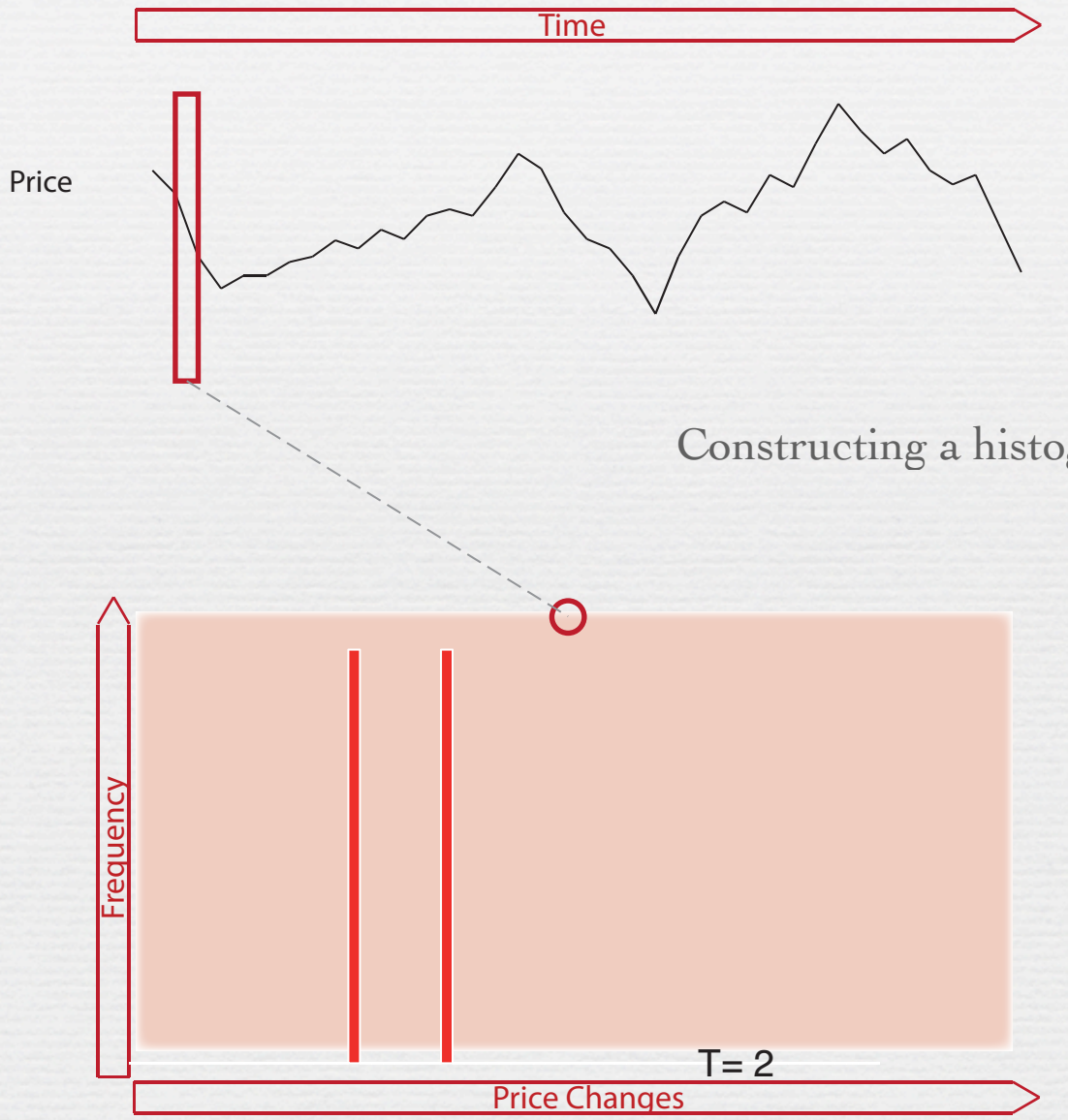
"Econostatics"



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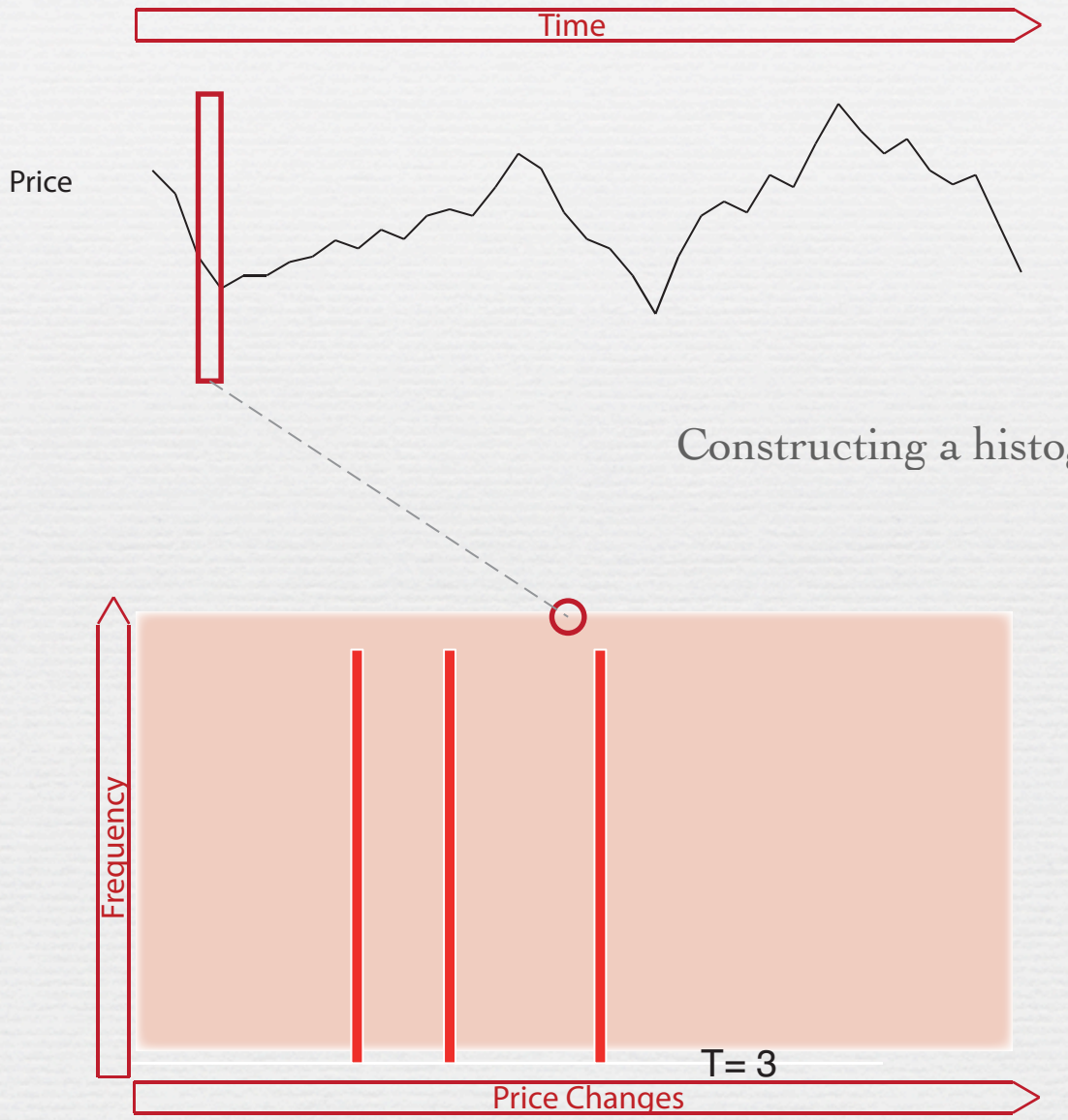
"Econostatics"



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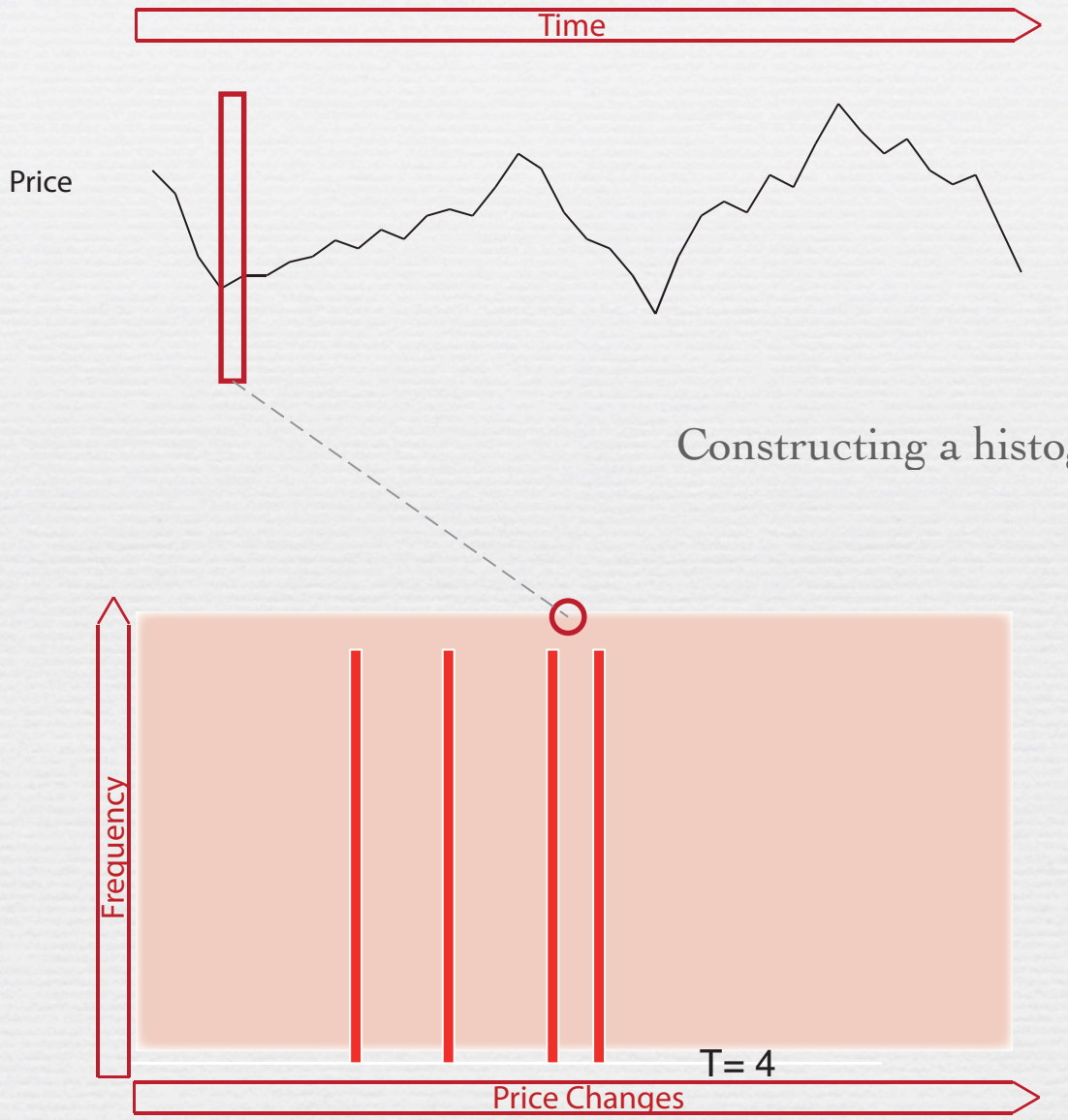
"Econostatics"



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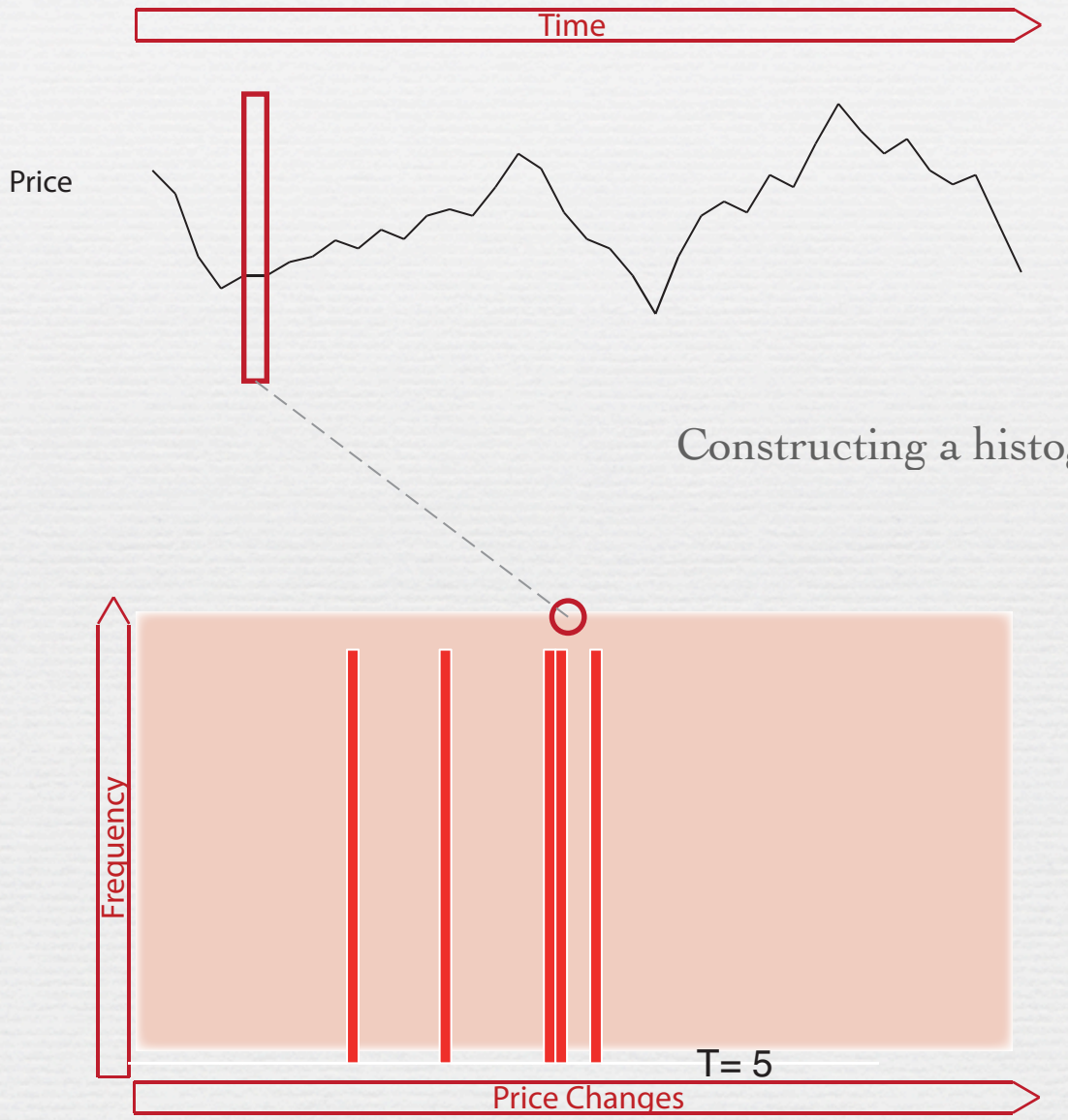
"Econostatics"



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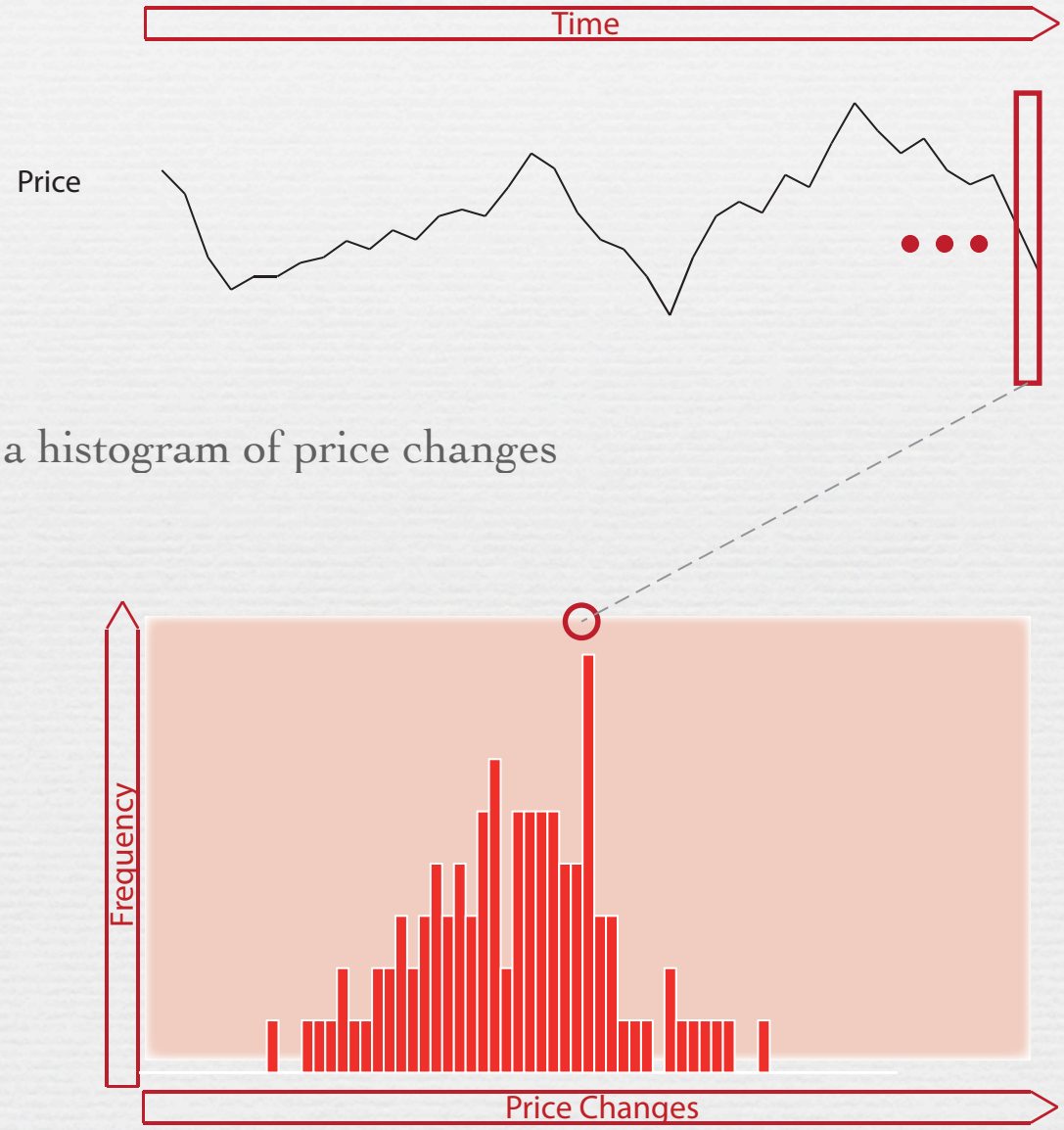
"Econostatics"



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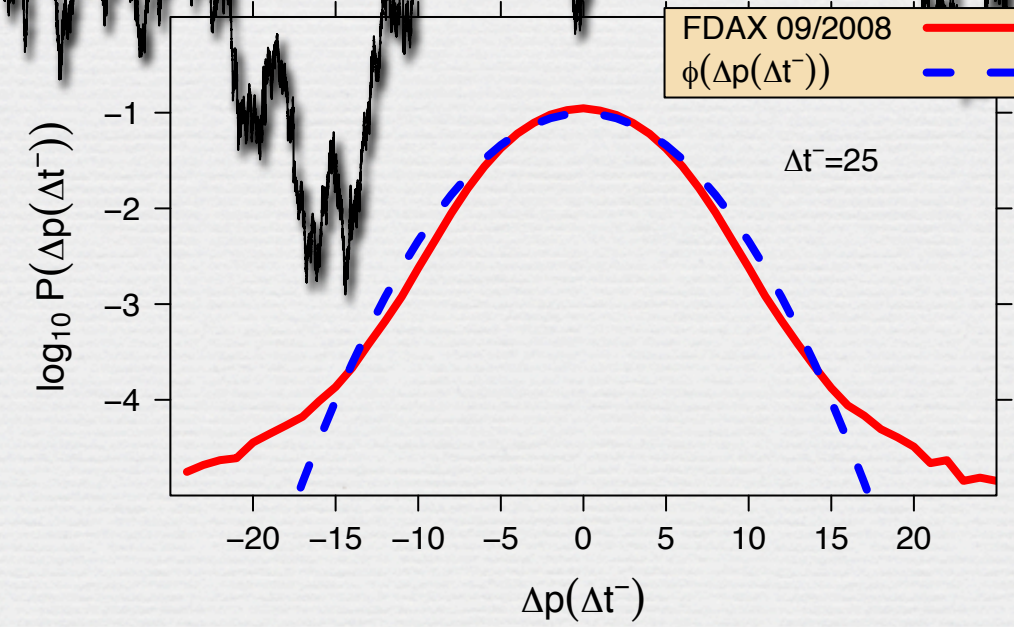
German Stock Index (DAX)

20.06.2008

15.09.2008

LEHMAN BROTHERS

19.09.2008



$$\phi(\Delta p(\Delta t^-)) = u \exp(-v\Delta p^2)$$

X. Gabaix et al., Nature **423**, 267-270 (2003).

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Milestones of trading

CBOT trading pit, Chicago, 1993

Floor trading

Electronic trading

1602 Options on shares of East-Indian Company (NL)

1634-36 Tulip bulb speculation bubble (NL)

...

1848 CBOT: trading of future contracts (USA)

...

1978 CBOE: trading of option contracts (USA)

...

1990 DTB: futures and options (D)

...

1998 EUREX: DTB+SOFFEX (D, CH)

...

Deutsche Bank AG headquarter, Frankfurt, 2007

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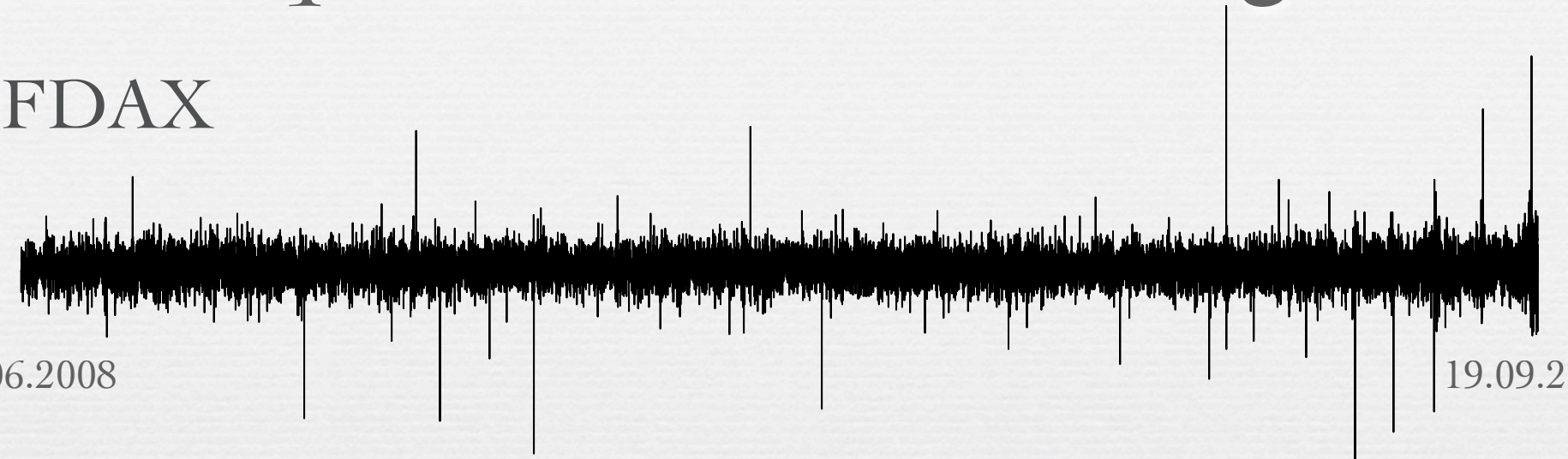
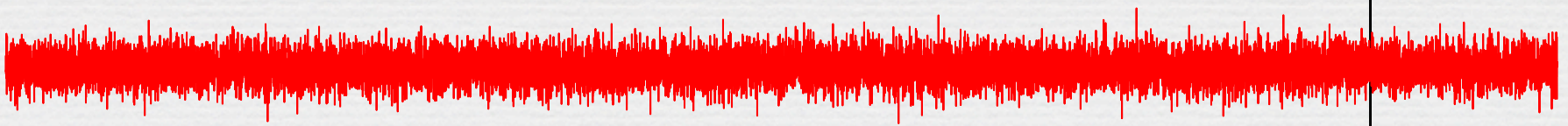
Sequence of Price Changes

FDAX



Random Walk



- **Empirical stylized facts of financial time series include:**
- Fat-tailed return distributions / Power law (**Gene Stanley et al.**)
- Log-periodic power law / Bubble detection (**Didier Sornette et al.**)
- Non-trivial scaling behavior of the returns,
- Volatility clustering
- ...

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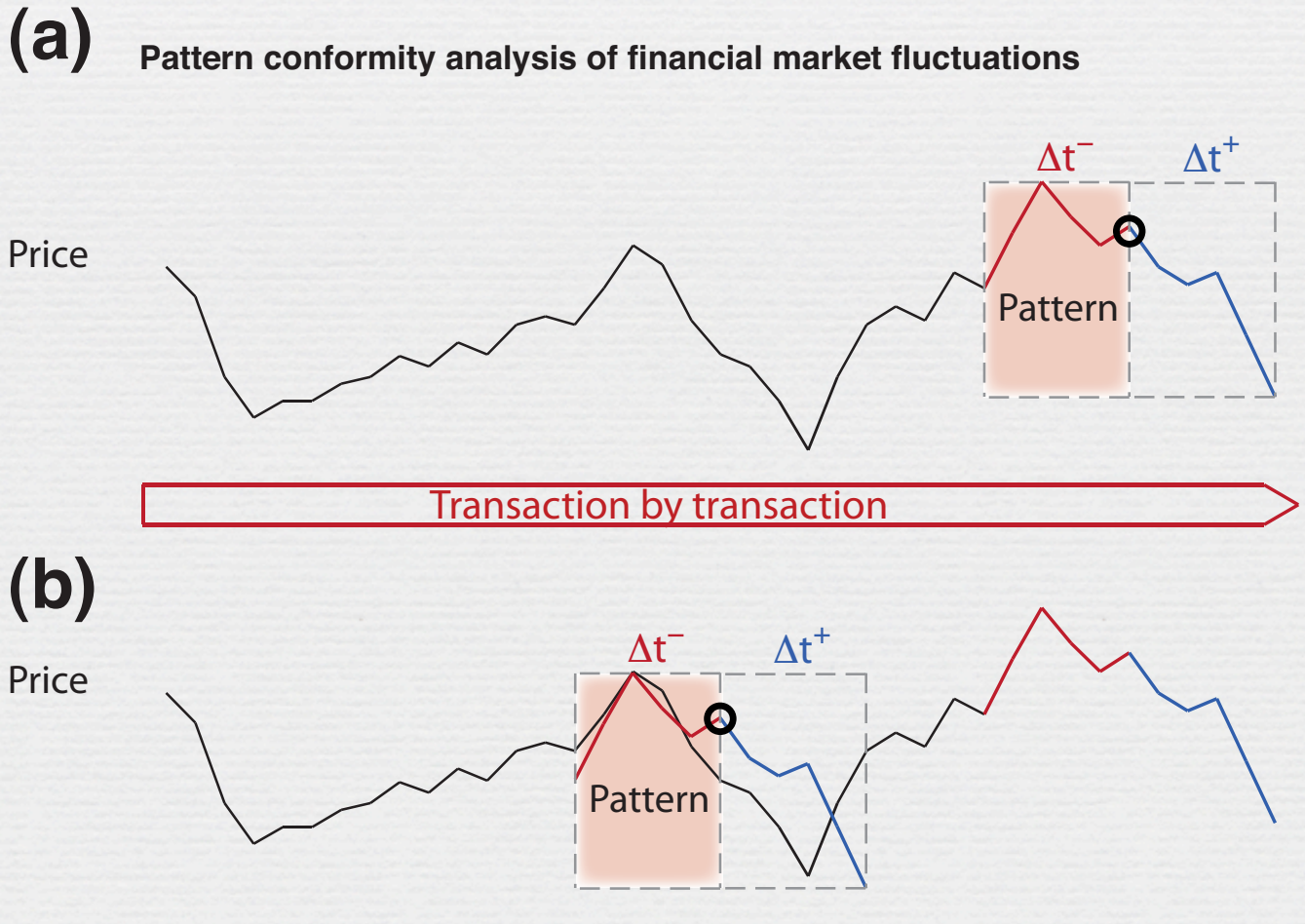
Fluctuation Patterns

„The aim is to compare the current reference pattern of time interval length Δt^- with all previous patterns in the time series.“



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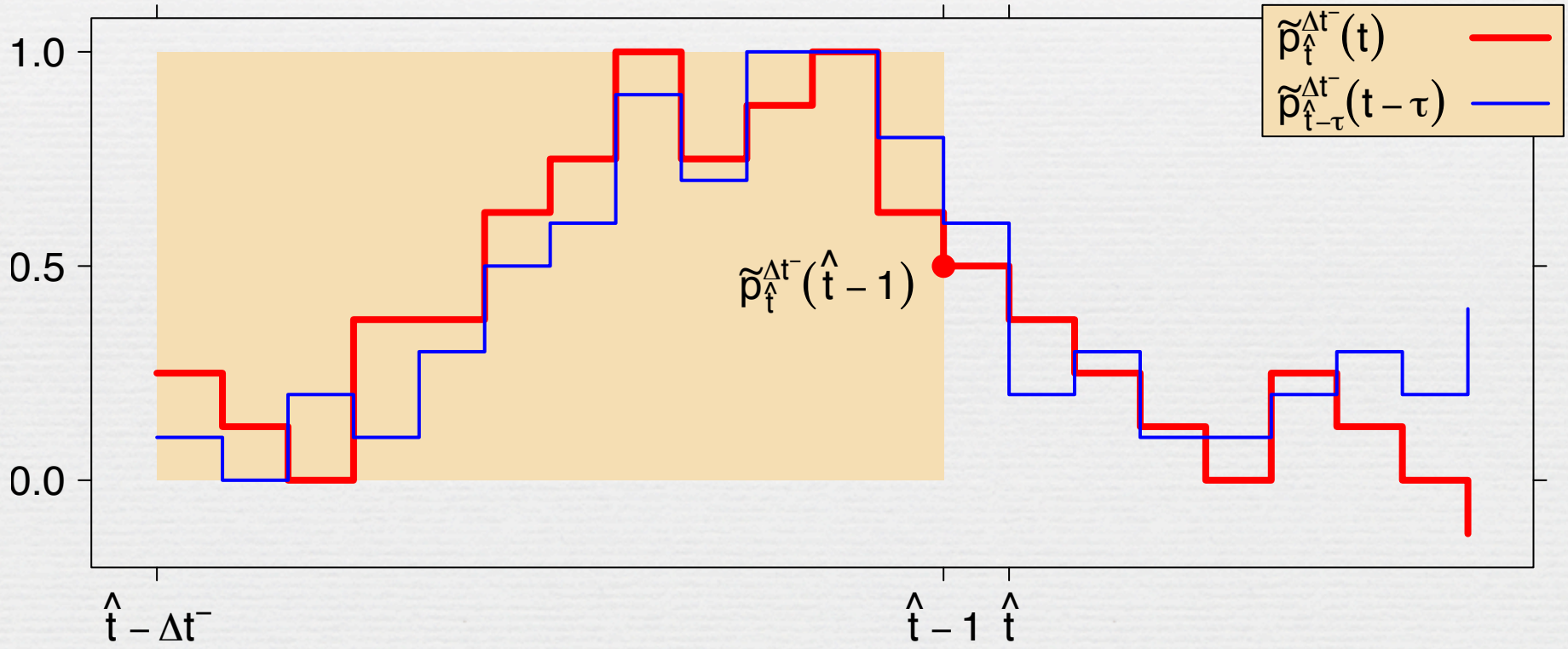
Fluctuation Patterns

True range adapted modified time series



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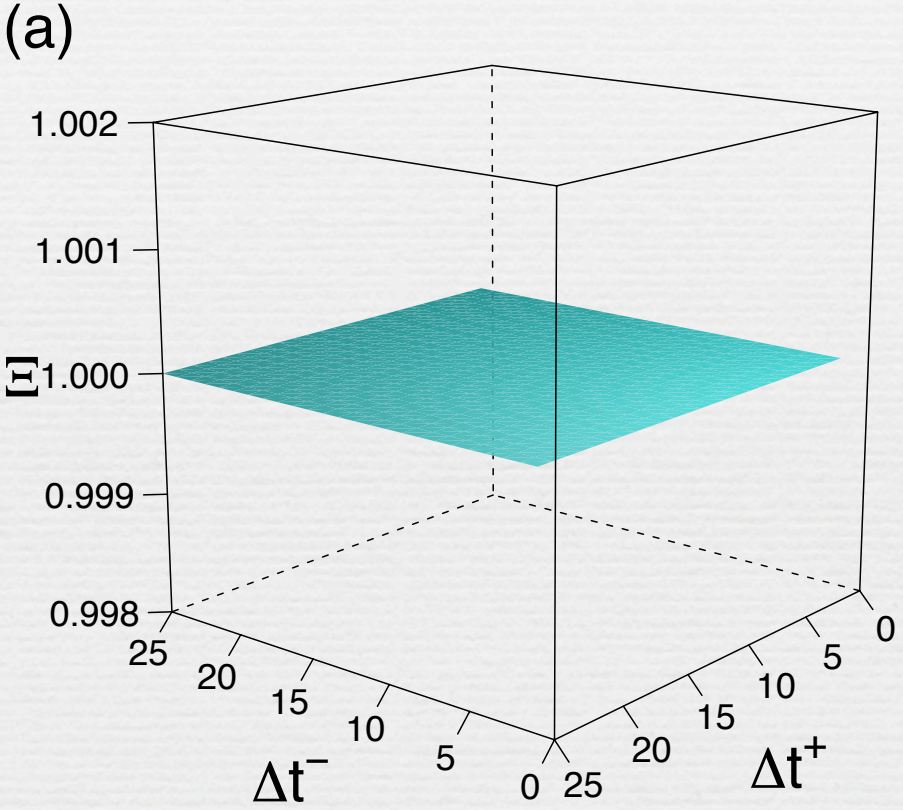
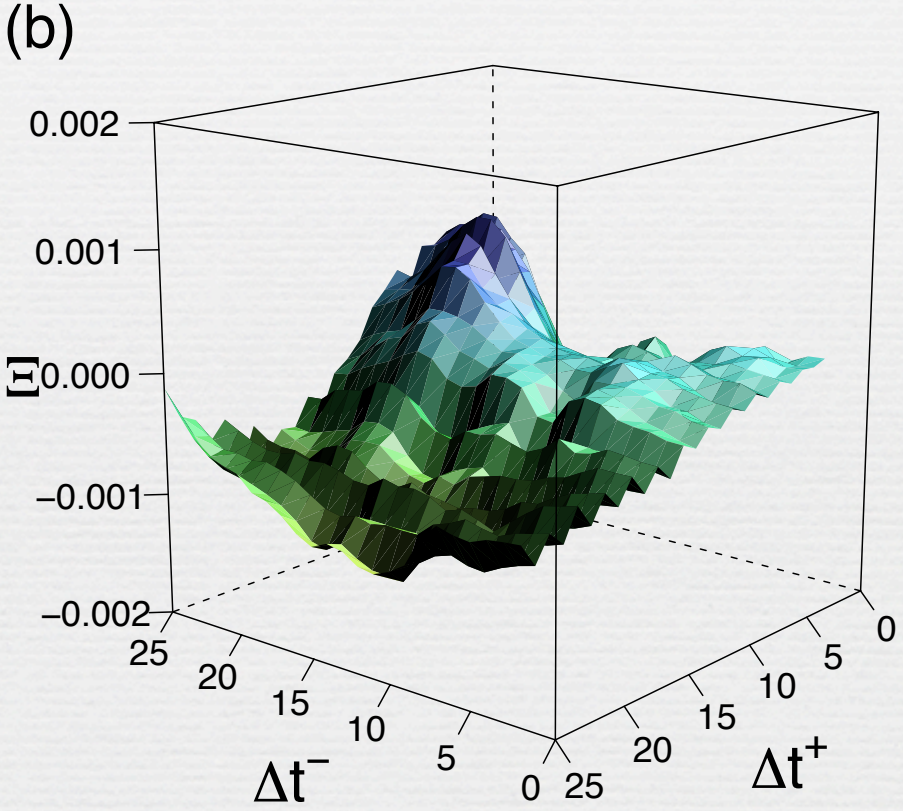
T. Preis, W. Paul, and J. J. Schneider, Europhys. Lett. **82**, 68005 (2008)

T. Preis, D. Reith, and H. E. Stanley, Phil. Trans. R. Soc. A **368**, 5707-5719 (2010)

Pattern Conformity / Trivial Cases

- Straight Line
- Random Walk





$$\Xi_\chi\left(\Delta t^+,\Delta t^-\right) = \frac{\xi_\chi\left(\Delta t^+,\Delta t^-\right)}{\sum_{\hat{t}=\Delta t^-}^{T-\Delta t^+}\sum_{\tau=\tau^*}^{\hat{t}} \frac{\left|\mathrm{sgn}\left(\omega_{\hat{t}}^{\Delta t^-}(\tau,\Delta t^+)\right)\right|}{\exp\left(\chi Q_{\hat{t}}^{\Delta t^-}(\tau)\right)}}$$

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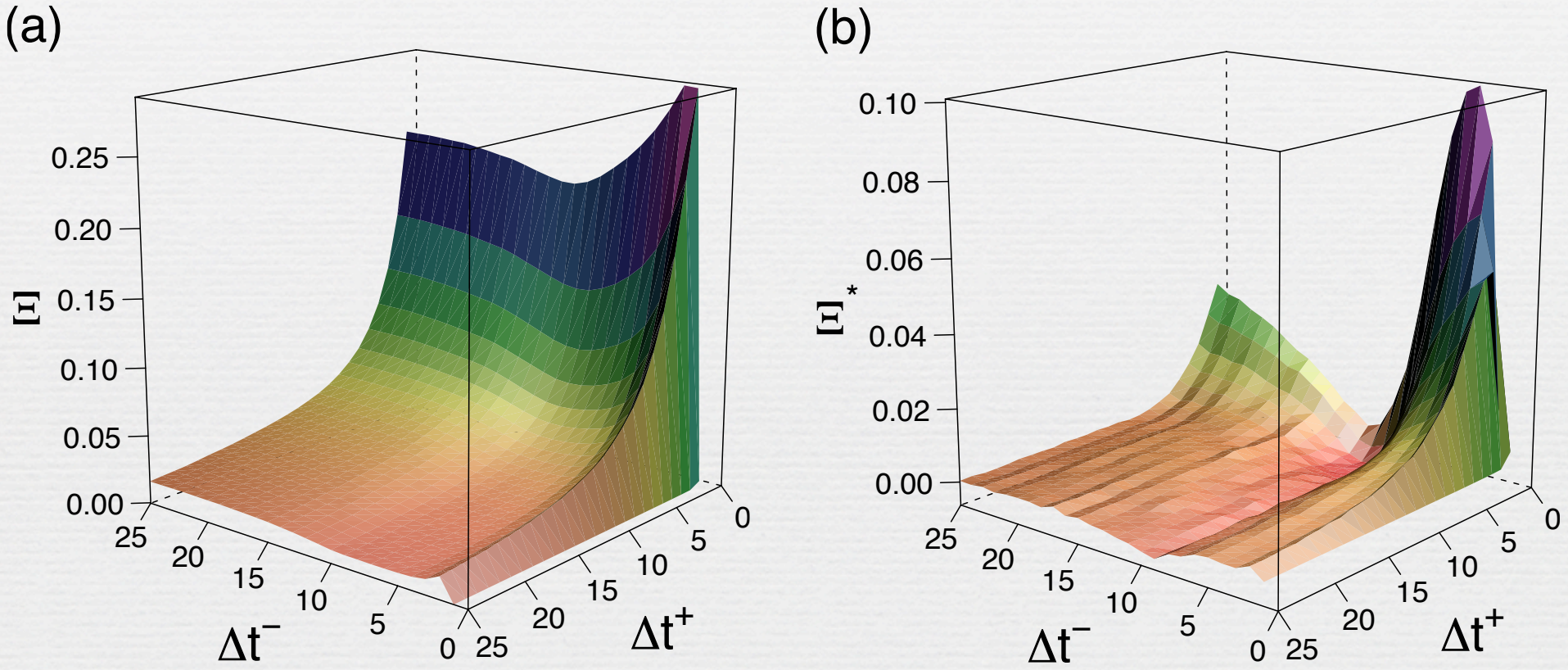
Pattern Conformity / FDAX



Complex correlations for financial market time series – especially for large pattern lengths.

T. Preis, P. Virnau, W. Paul, and J. J. Schneider, New J. Phys. **11**, 093024 (2009)

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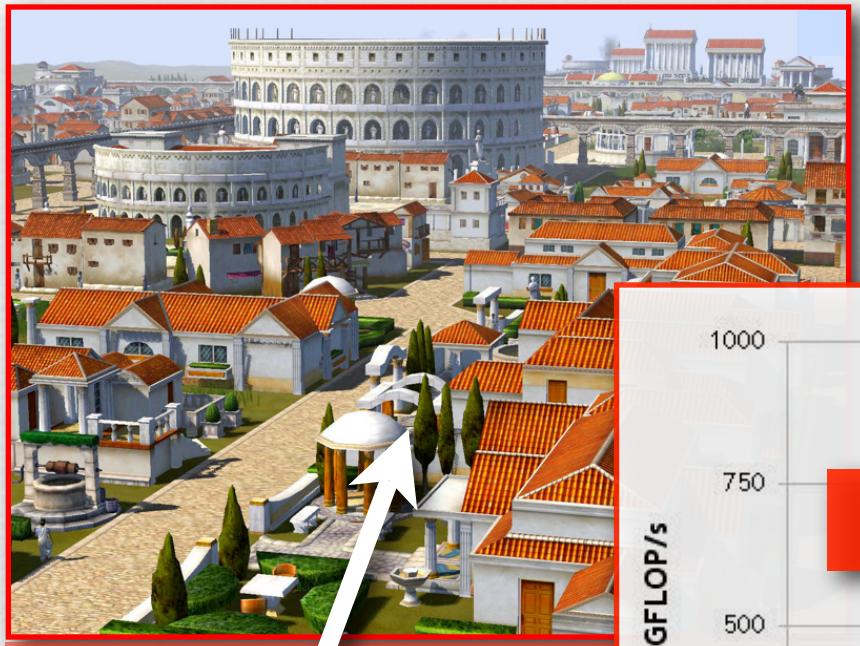
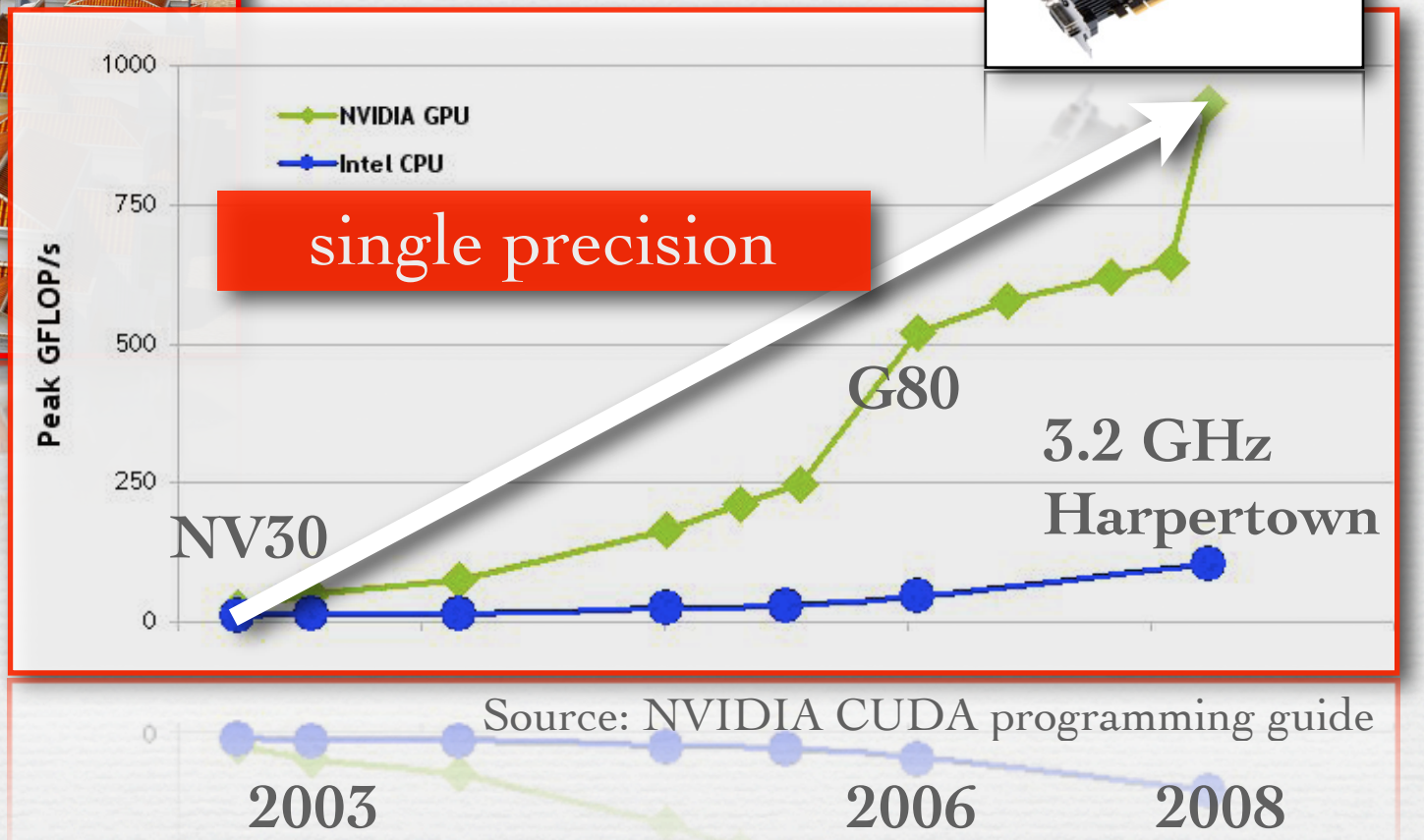
GPU-Computing



GT200



Realistic illustrations
Driving force:
computer game
industry

Source: NVIDIA CUDA programming guide

Outline

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2007 1 2 8 0 12 55 6674 1
2007 1 2 8 0 12 55 6674.5 2
2007 1 2 8 0 14 20 6673 1
2007 1 2 8 0 15 25 6672.5 1
2007 1 2 8 0 15 25 6673 3
2007 1 2 8 0 15 62 6673 1
2007 1 2 8 0 15 62 6674 4
2007 1 2 8 0 19 16 6673 1
2007 1 2 8 0 19 16 6673.5 1
artemis-2:eurex_time_series tobias$

Time Series
–
Data Structure

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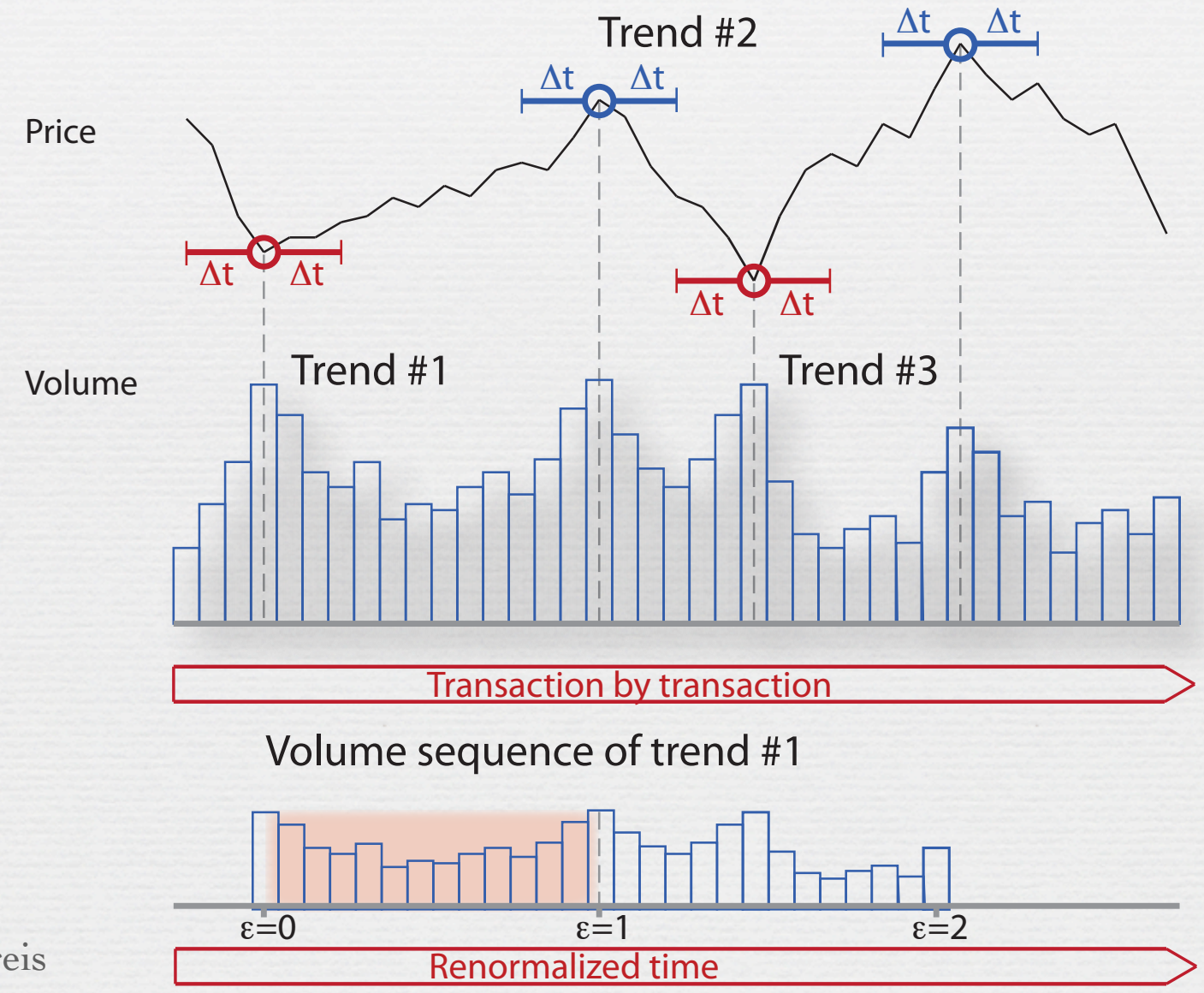
Rescaling Analysis

(a) **Determination of local price extrema and renormalization**



13,991,275 trades

FDAX
– June 2007
– September 2008
– December 2008

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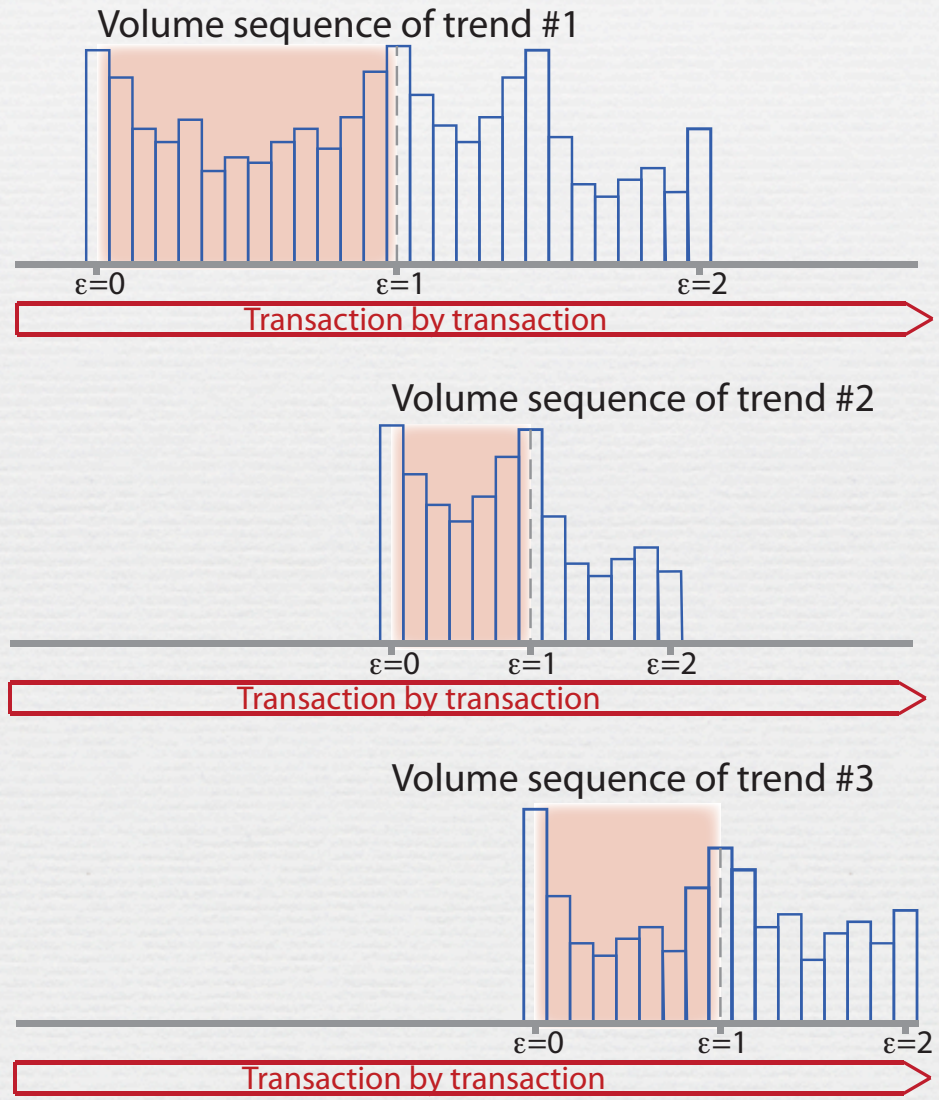
Rescaling Analysis

Extraction of trend sequences



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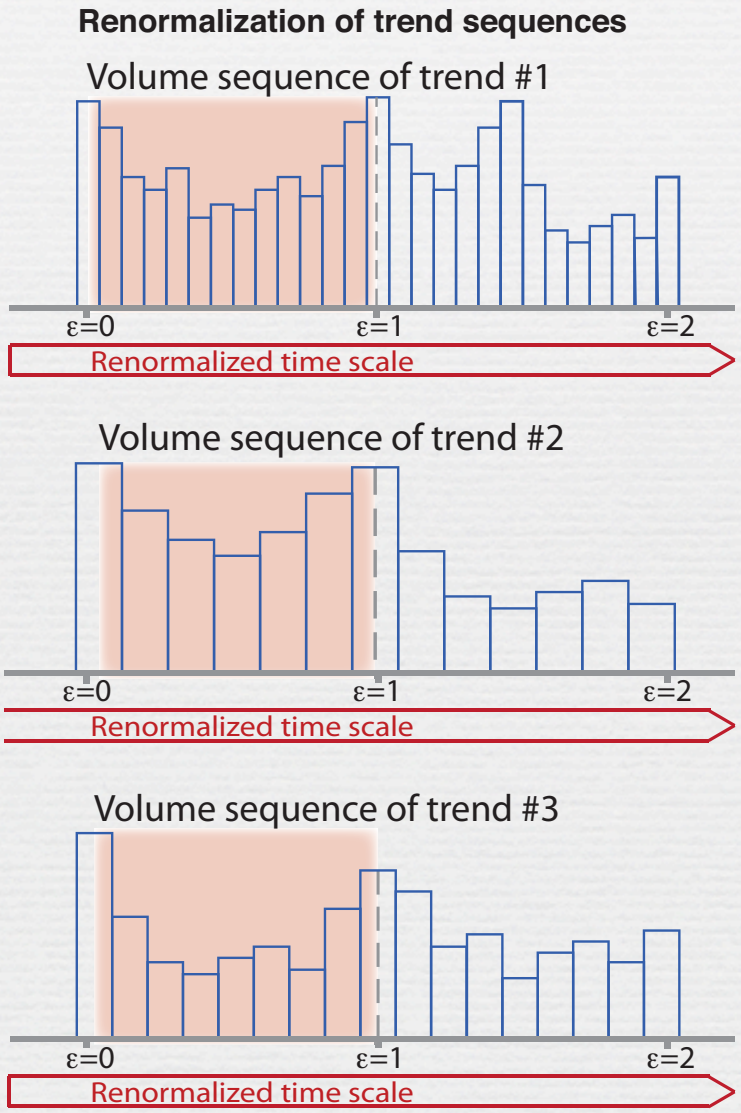
Rescaling Analysis



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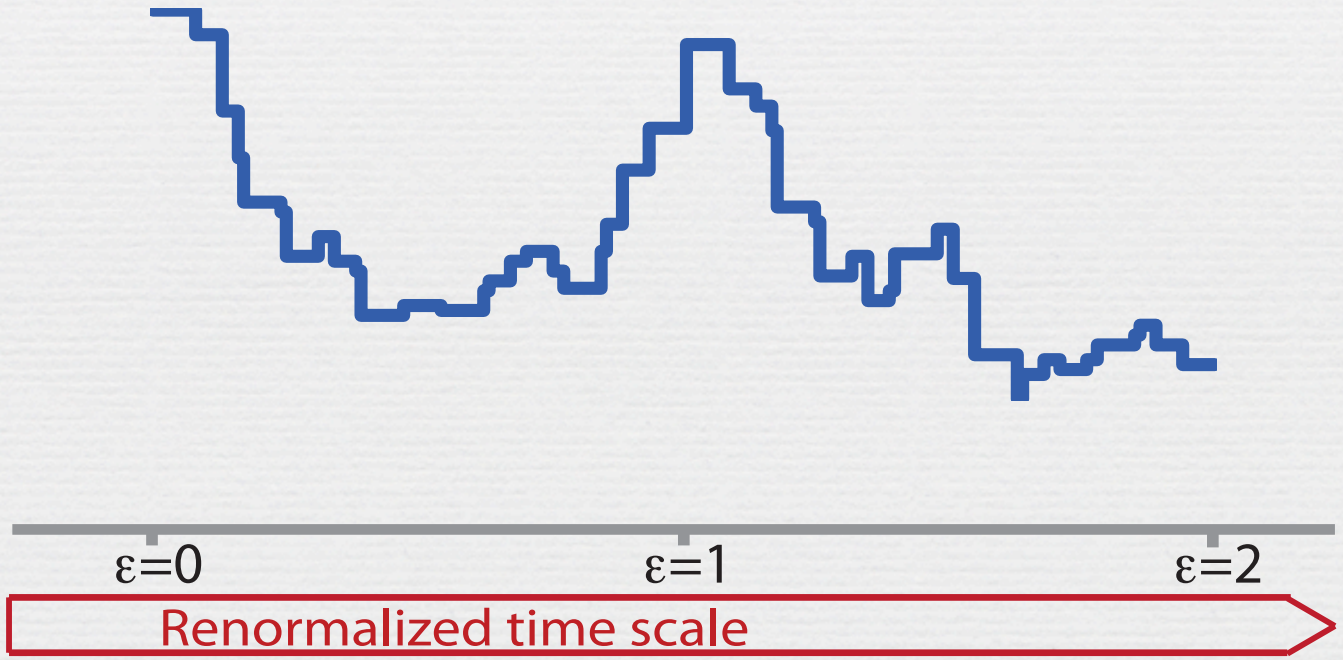
Rescaling Analysis

Averaged volume sequence



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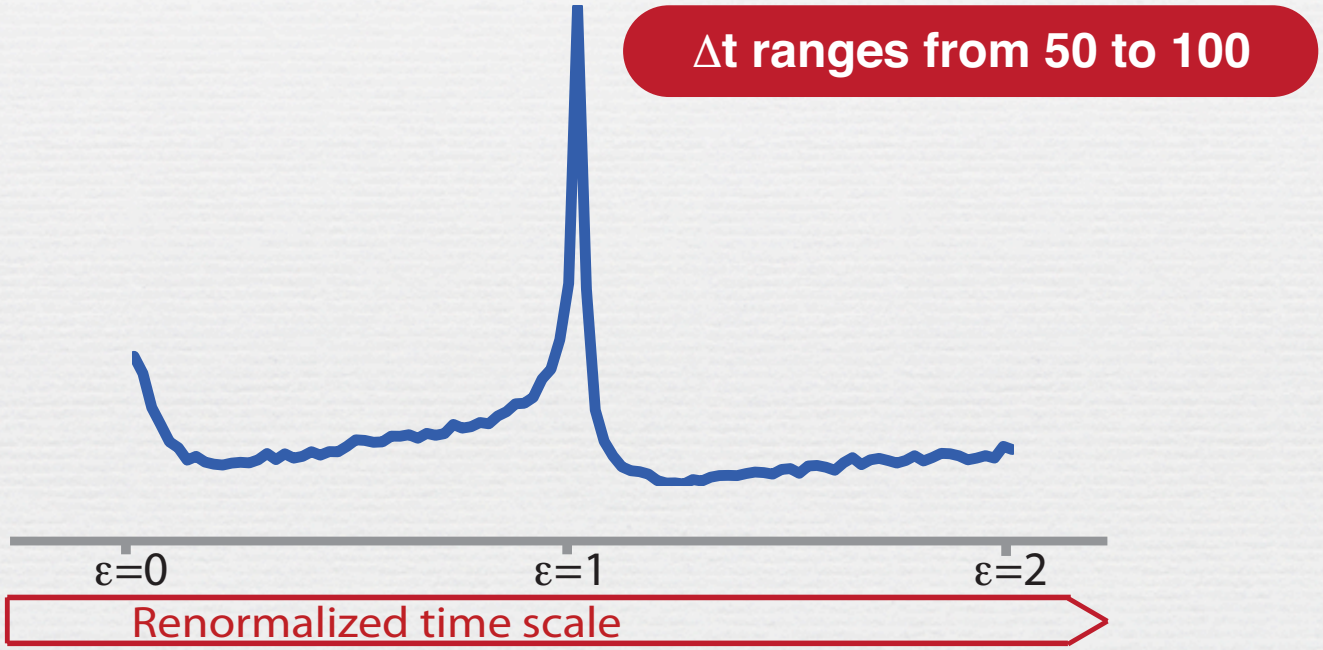
Rescaling Analysis

Averaged volume sequence for FDAX time series



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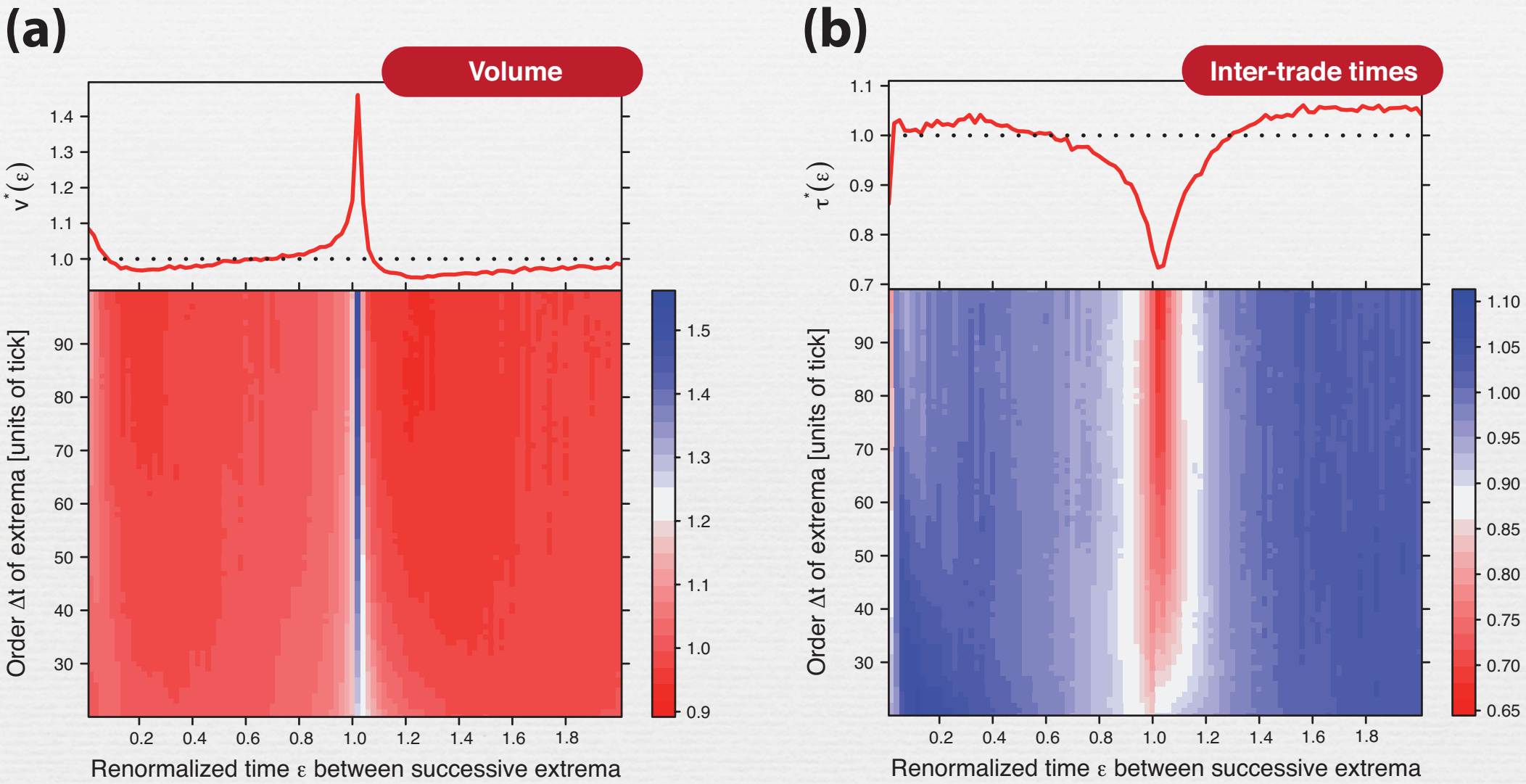

T. Preis and H. E. Stanley, APCTP Bulletin **23**, 18 (2009)

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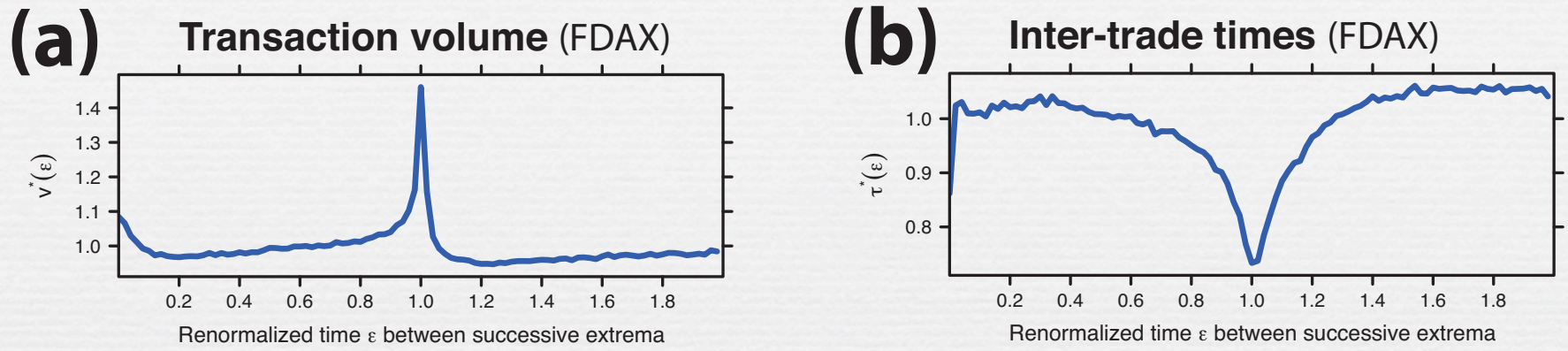
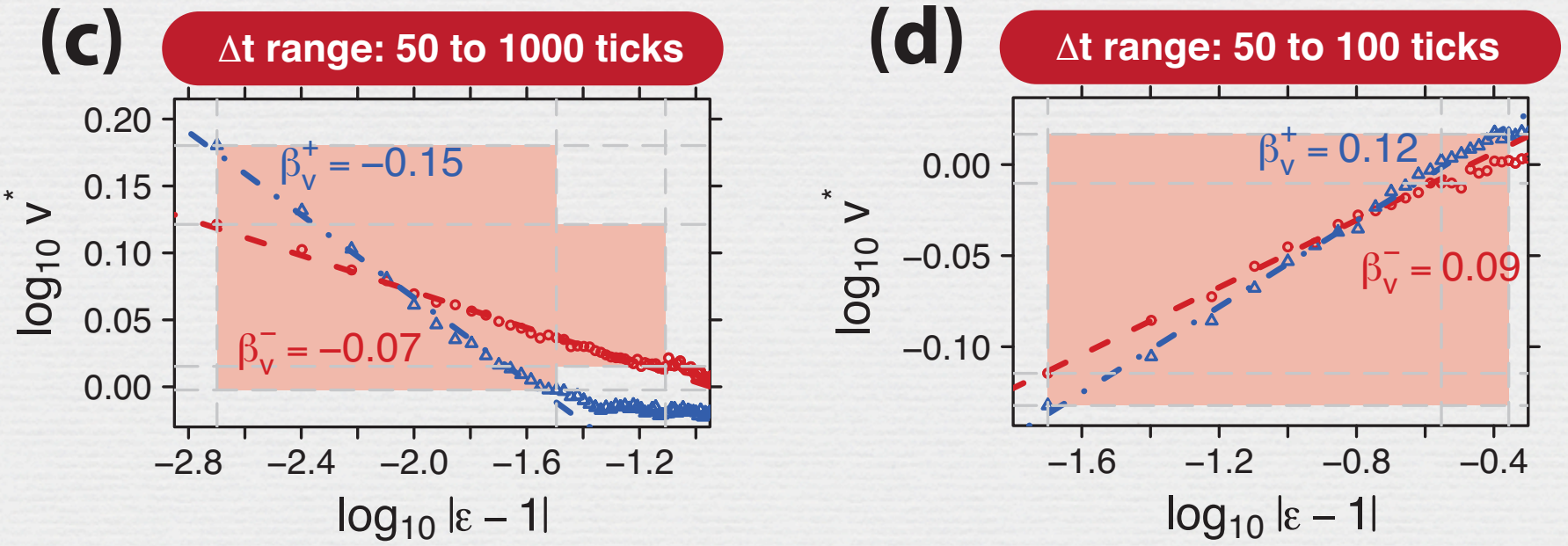
T. Preis and H. E. Stanley, J. Stat. Phys. **138**, 431 (2010)

T. Preis, J. J. Schneider, and H. E. Stanley, accepted for publication in PNAS (2010)

Quantities With Scale-Free Behavior





- Randomly reshuffling confirms our findings.

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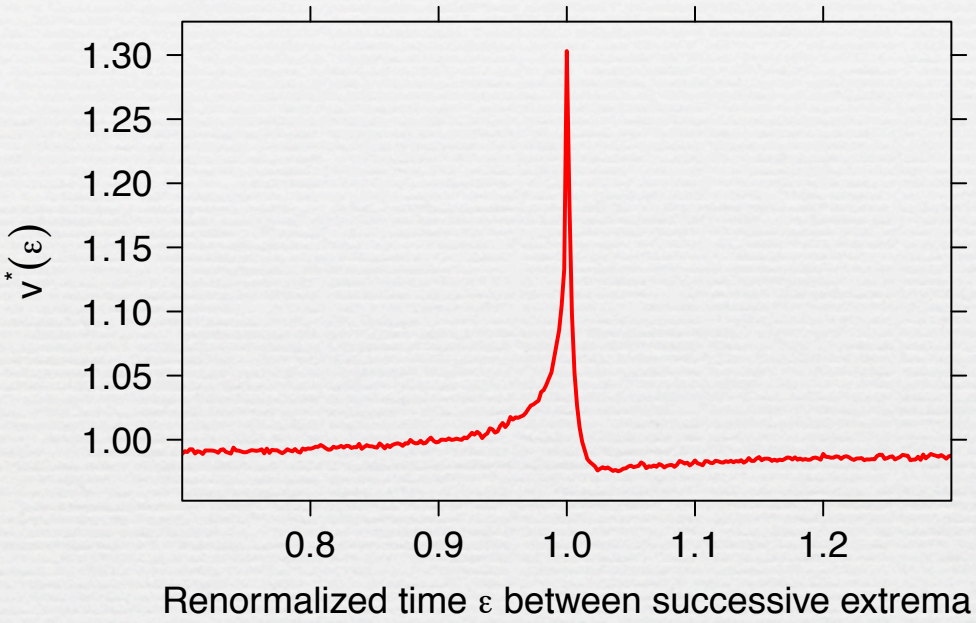
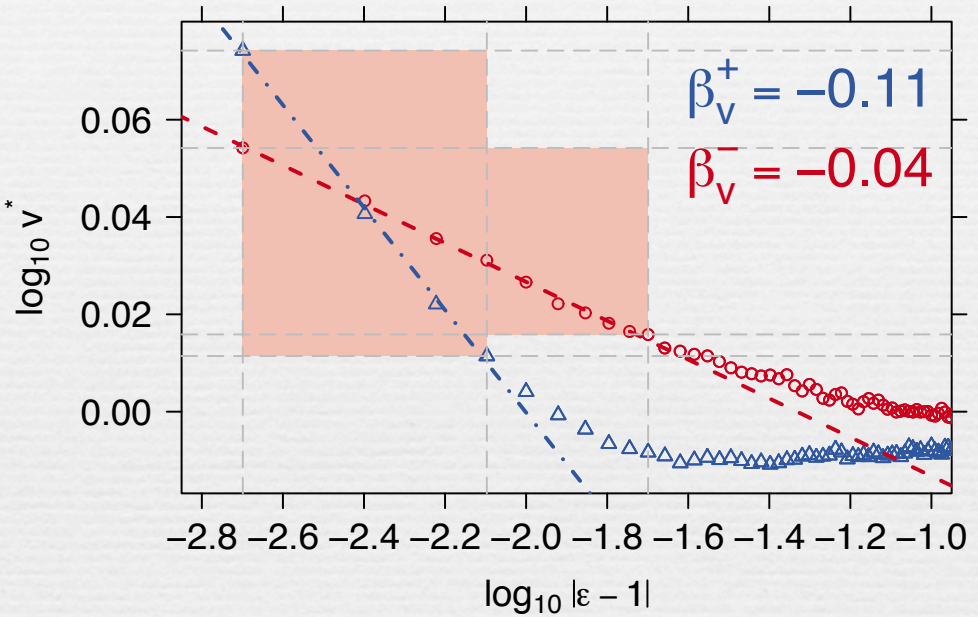
Reproduction with a Model





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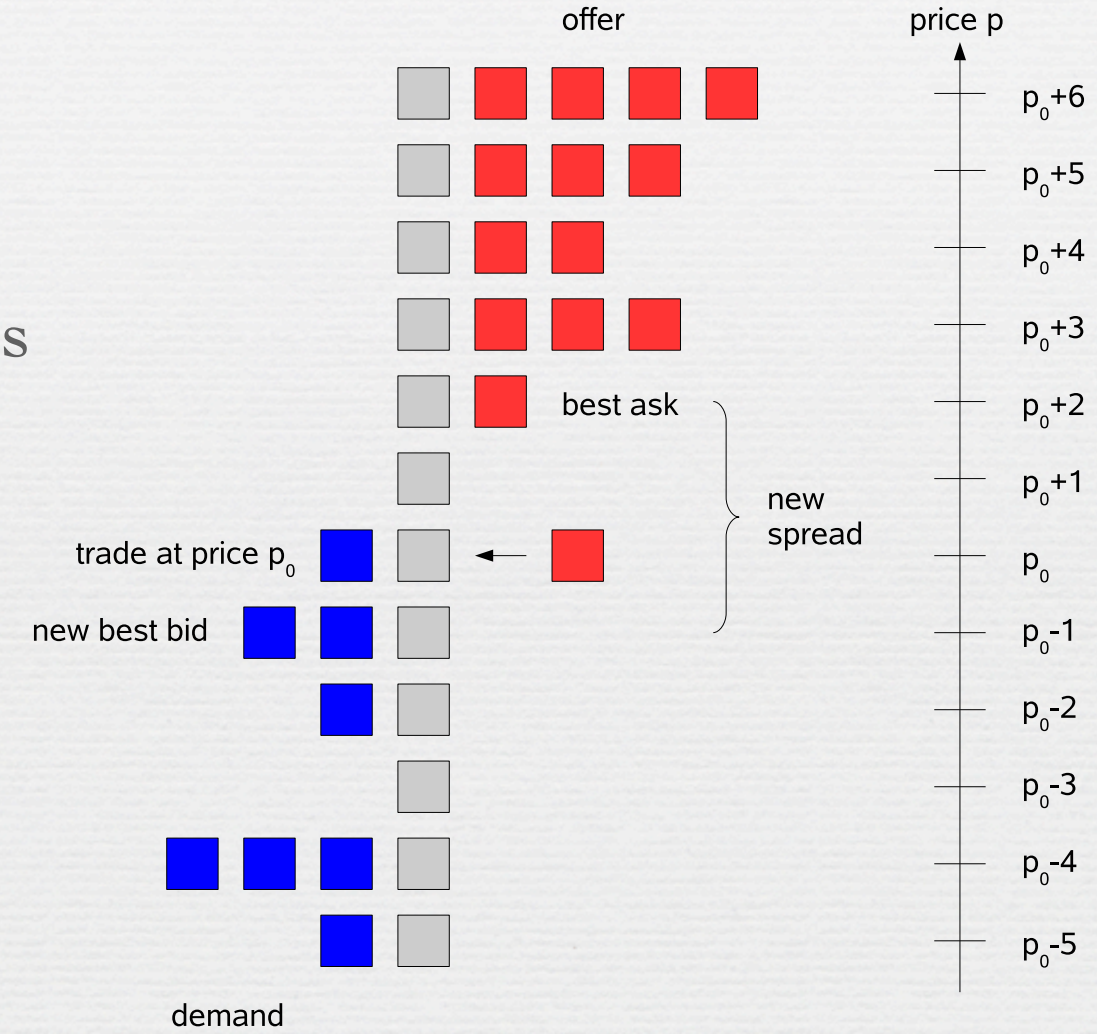
Order Book Structure

- Price-time priority
- Discrete price levels
- Limit orders
- Market orders



T. Preis, S. Golke, W. Paul, and J. J. Schneider, Europhys. Lett. **75**, 510 (2006)

T. Preis, S. Golke, W. Paul, and J. J. Schneider, Phys. Rev. E **76**, 016108 (2007)

Model Definition

- Liquidity provider N_A
- Liquidity taker N_A
- Limit order rate α
- Market order rate μ
- Order cancel rate δ
- Buy/Sell probability $q_{\text{provider}} = q_{\text{taker}} = \frac{1}{2}$
- Best bid p_b
- Best ask p_a
- Midpoint $p_m = \frac{p_a + p_b}{2}$
- Spread $s = p_a - p_b$

Model Definition

- Exponentially distributed order entry depth
  - Limit price of a limit buy order

$$p_i^l = p_a - 1 - \eta$$

  - Limit price of a limit sell order

$$p_i^l = p_b + 1 + \eta$$

  - with stochastic variable $\eta = \lfloor -\lambda_0 \times \log(x) \rfloor$

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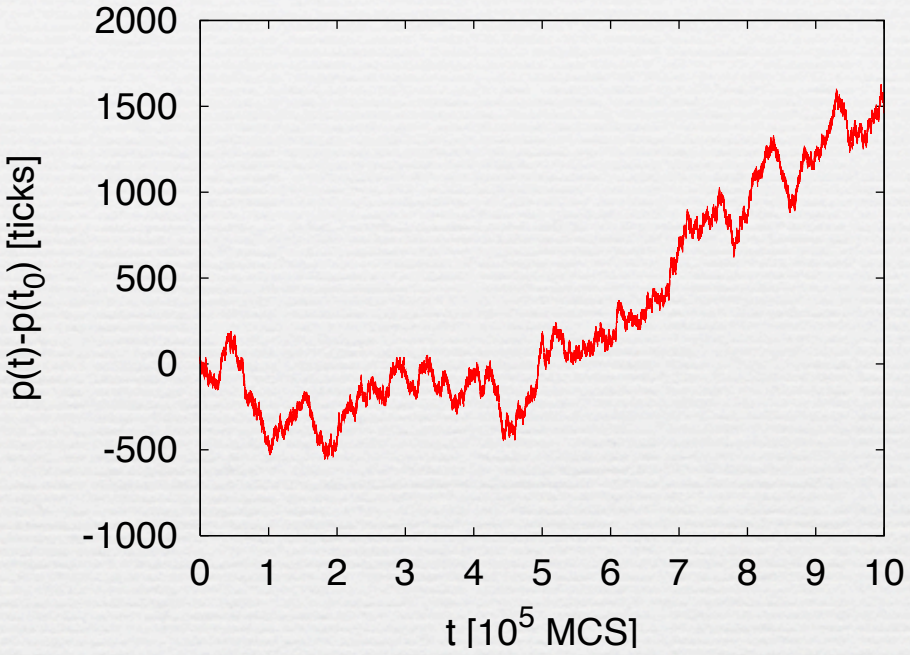
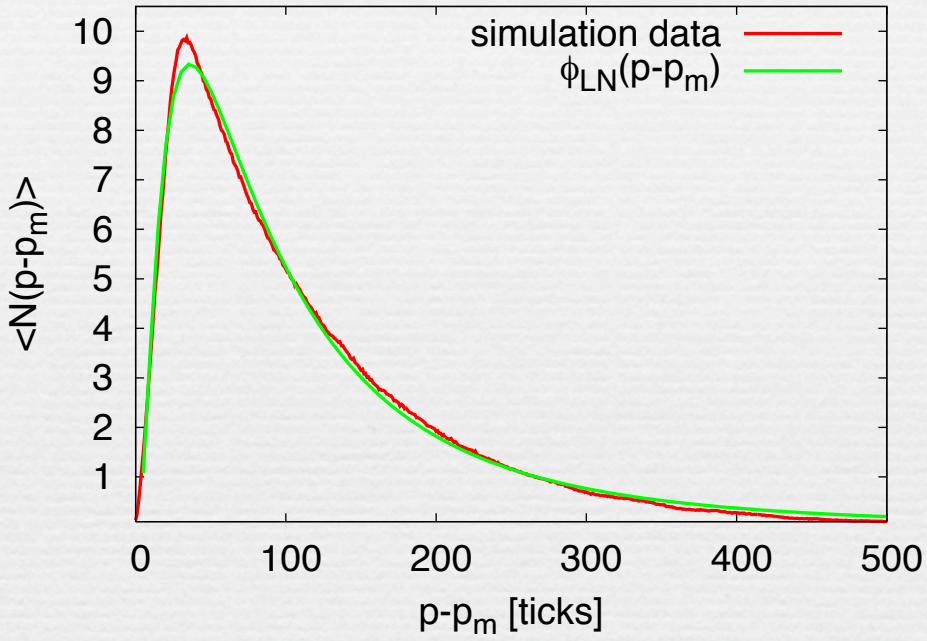
Results of the Model

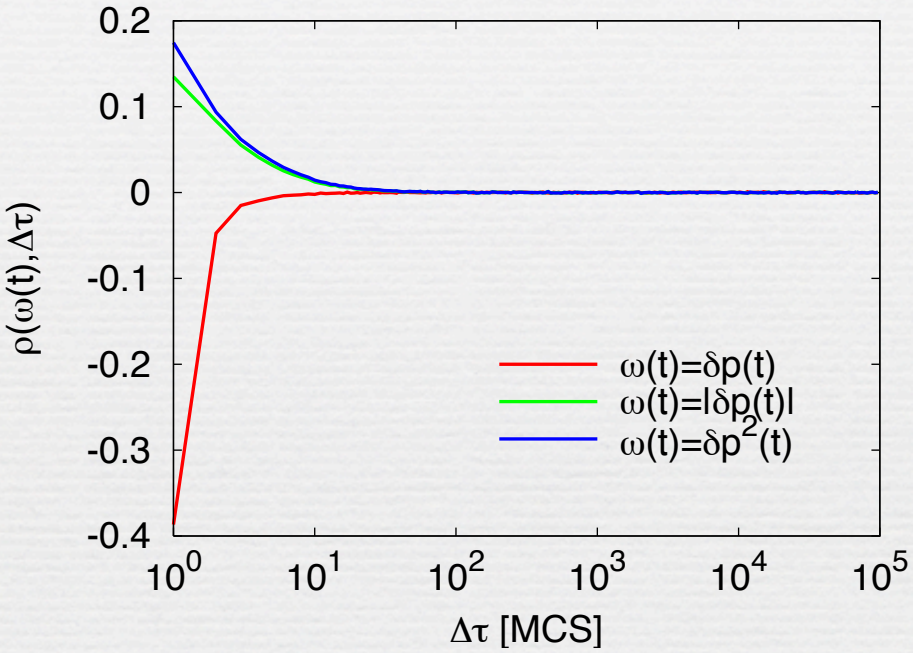




$$P_{\mathrm{LN}}(x) = A\,\frac{1}{Sx\sqrt{2\pi}}\,\exp\left(-\frac{(\ln x - M)^2}{2S^2}\right)$$

- Order book depth: log-normal distribution

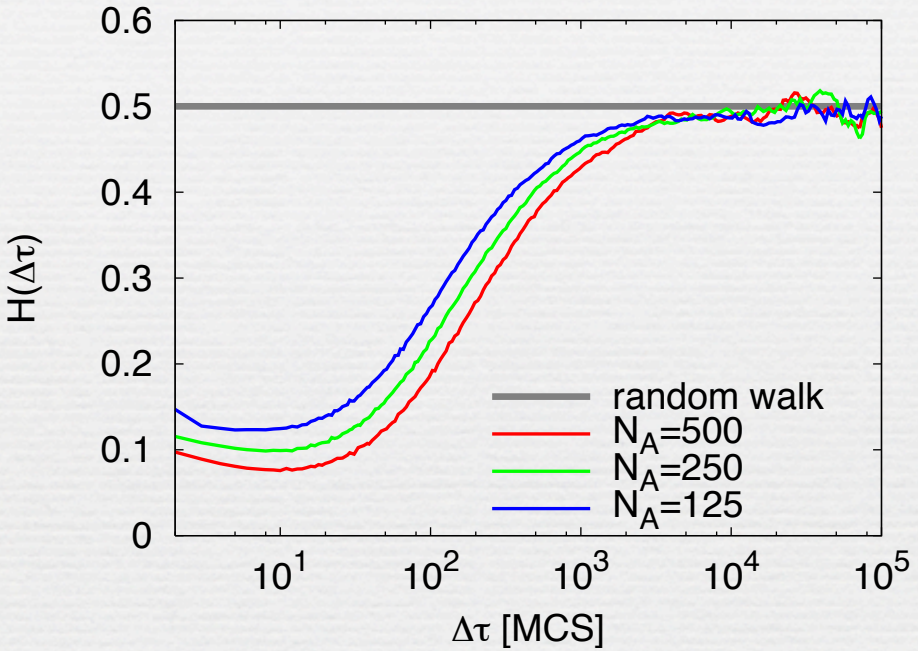
Autocorrelations

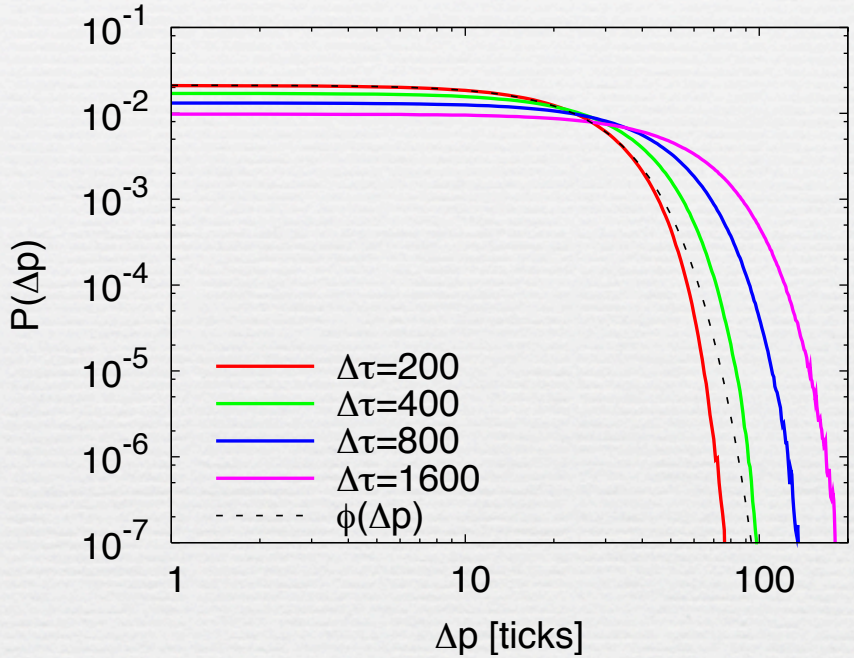


$$\varrho(\omega(t)\tau) = \frac{\langle \omega(t+\tau)\omega(t)\rangle - \langle \omega(t)\rangle^2}{\langle \omega(t)^2\rangle - \langle \omega(t)\rangle^2}$$

- Negative autocorrelation on short time scales
- Volatility clustering

Results of the Model





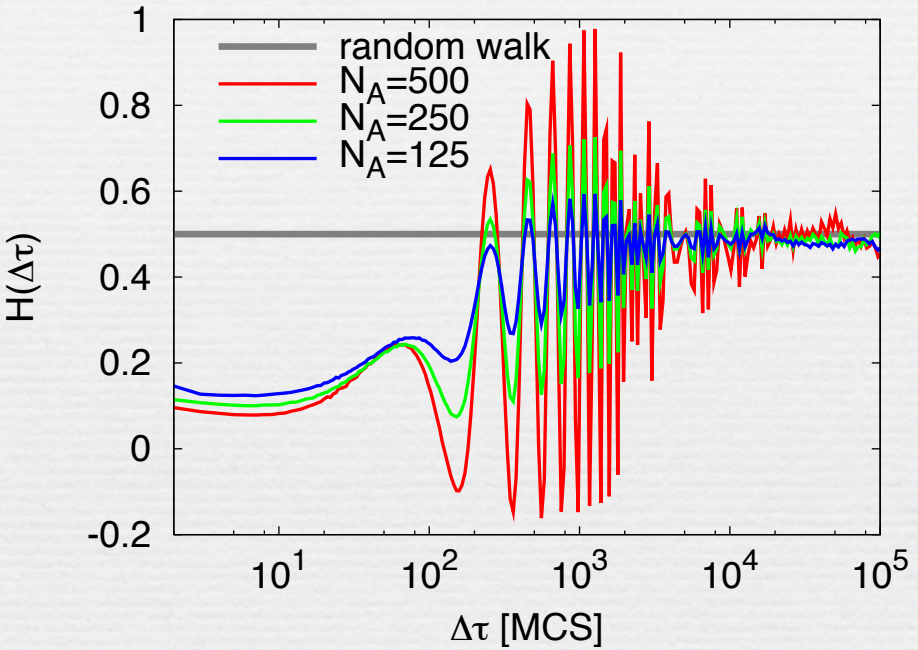
- Hurst exponent $H(\Delta\tau)$: $\langle(\Delta p)^2\rangle^{1/2}(\Delta\tau) \propto \Delta\tau^H$
- Random walk: $H = 1/2$

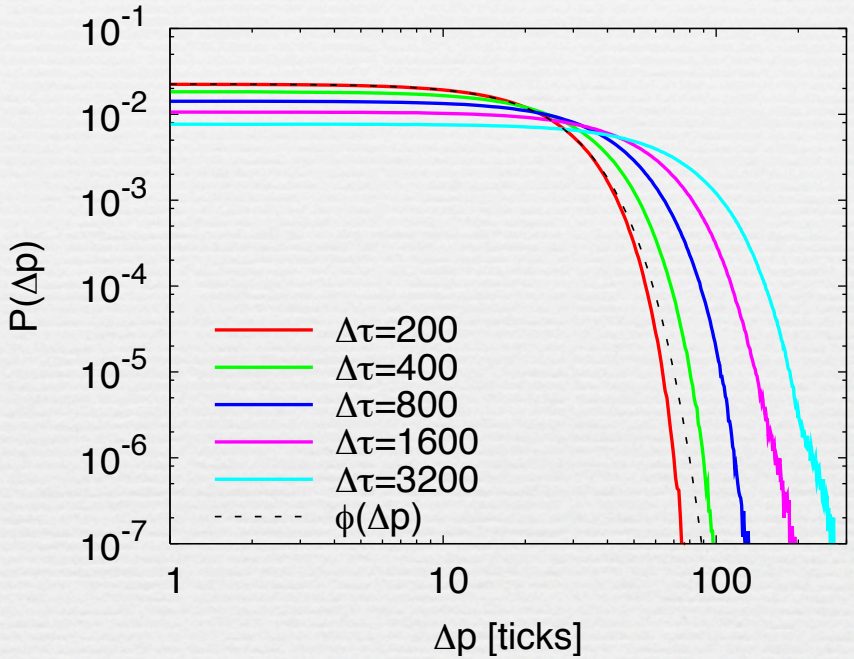
Asymmetric Order Flow

- Time dependent buy/sell probability (micro trends):
  - Deterministic perturbation: Sawtooth
  - Stochastic perturbation: Feedback random walk (FRW): RW with mean reversion tendency

T. Preis, S. Golke, W. Paul, and J. J. Schneider, Europhys. Lett. **75**, 510 (2006)

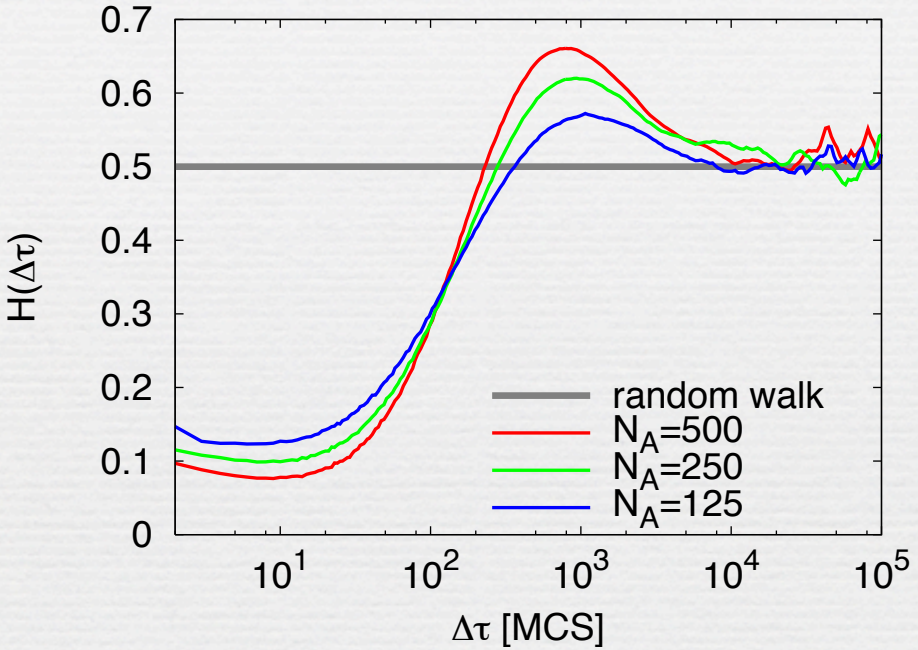
Sawtooth

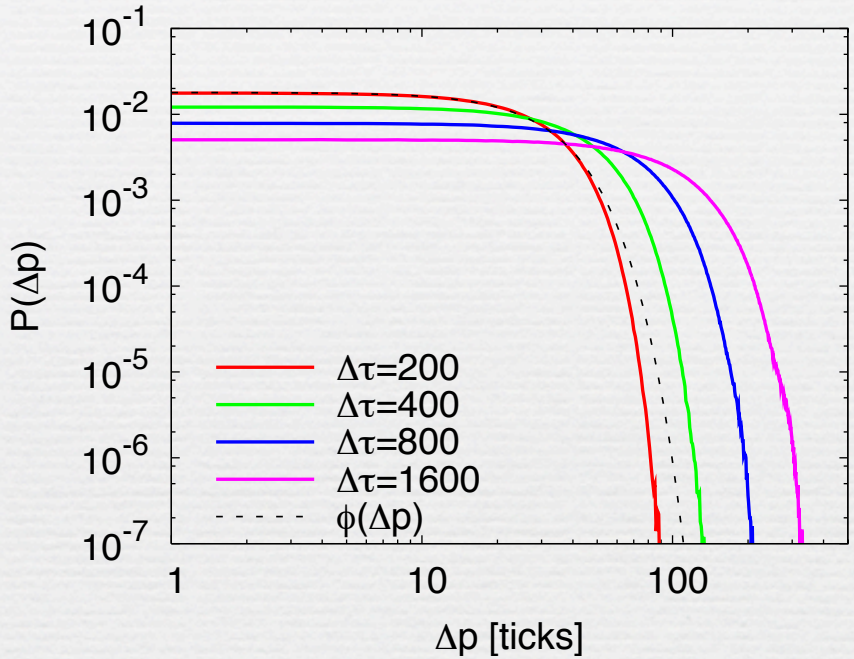




- Deterministic modulation with a period of 200 MCS is reflected in the mean square displacement, leading to quasi-periodic oscillations of the Hurst exponent.

Feedback Random Walk





- Again an anti-persistent behavior on short time scales, but a persistent behavior on medium time scales, and a diffusive regime on long time scales.

T. Preis, J. Phys.: Conf. Ser. **221**, 012019 (2010)

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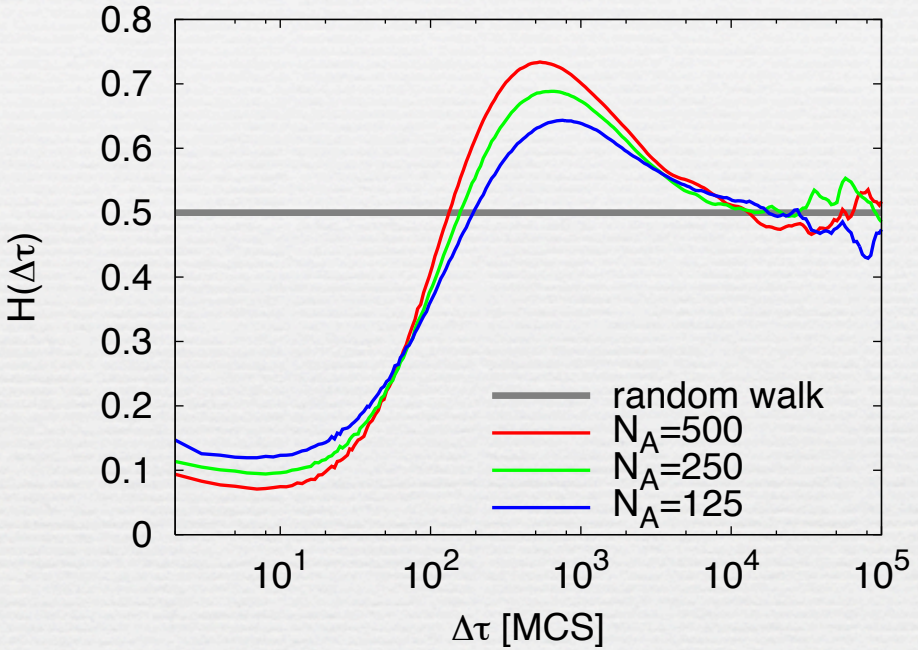
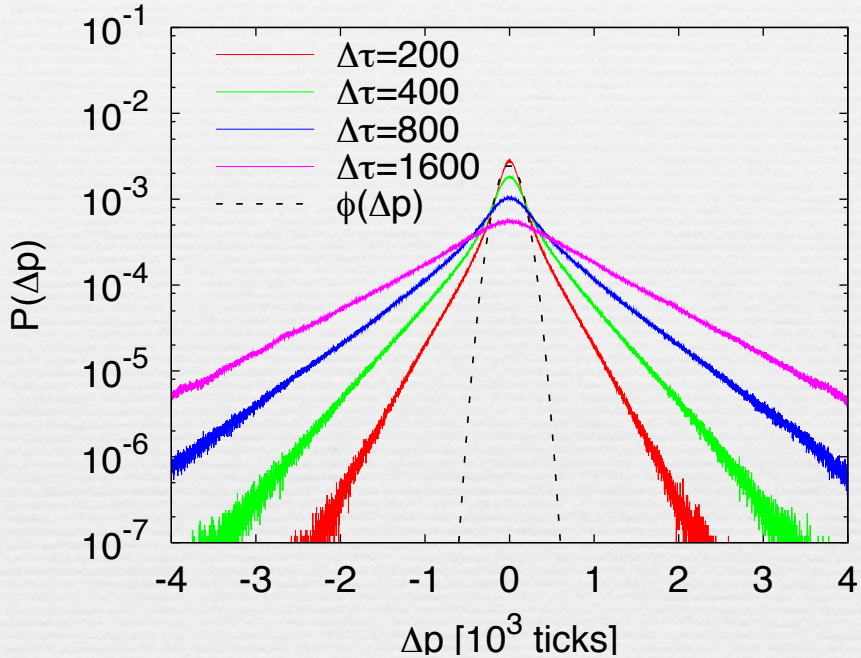
Dynamic Order Depth





- Hurst exponent H

$$\langle |p(t+\Delta t) - p(t)|^q \rangle^{1/q} \propto \Delta t^{H_q(\Delta t)}$$

- Dynamic order entry depth leads to fat-tailed distribution of price changes

T. Preis, S. Golke, W. Paul, and J. J. Schneider, Europhys. Lett. **75**, 510 (2006)

T. Preis, S. Golke, W. Paul, and J. J. Schneider, Phys. Rev. E **76**, 016108 (2007)

Conclusions

- **Complex pattern-based correlations in high frequency financial market data.**
- Switching processes in financial markets: Power-law behavior close to switching points.
- Order Book Model: Reproduction of anti-persistent scaling behavior on short time scales, persistent on medium time scales, and diffusive behavior on long time scales; fat-tailed price change distributions.
- Reproduction of switching point behavior.

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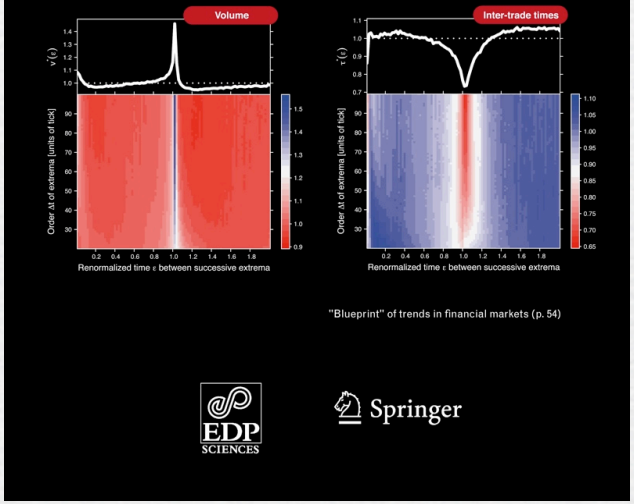
Thank you ...

EPJ ST: Issue 194




TOPICS IN PHYSICS

How to Characterize Trend Switching Processes in Financial Markets

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One of the key conceptual elements in modern statistical physics is the concept of scale invariance, codified in the scaling hypothesis that functions obey certain functional equations whose solutions are power laws. The scaling hypothesis has two categories of predictions, both of which have been verified by a wealth of experimental data on diverse systems. The first category is a set of relations, called scaling laws, that serve to relate the various critical-point exponents characterizing the singular behavior of functions such as thermodynamic functions. The second category is a sort of data collapse, where under appropriate axis normalization, diverse data "collapse" onto a single curve.

Econophysics research has been addressing a key question of interest: focusing on the challenge of quantifying the behavior of probability distributions of large fluctuations of relevant variables such as returns, volumes, and the number of transactions. Sampling the fat tails of such distributions requires a large amount of data. However, there is a truly gargantuan amount of pre-existing precise financial market data already collected, many orders of magnitude more than for typical complex systems. Accordingly, financial markets are becoming a paradigm of complex systems, and increasing numbers of scientists are analyzing market data [1-7]. Empirical analysis has been focused on quantifying and testing the robustness of power-law distributions that characterize large movements in stock market activity. Using estimators that are designed for serially and cross-sectionally independent data, findings support the hypothesis that the power law exponents that characterize fluctuations in stock price, trading volume, and the number of trades [8, 9] are seemingly "universal" in the sense that they do not change their values significantly for different

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H. Eugene Stanley is a University Professor in the Department of Physics and Director of the Center for Polymer Studies at Boston University. He had worked for MIT as a physics professor before he moved to Boston University. He also serves as editor-in-chief of Physica A and as editor of several journals including Quantitative Finance. He was elected to the National Academy of Sciences (USA) and was awarded the Boltzmann Medal from the International Union of Pure and Applied Physics (IUPAP) in 2004 for his contribution to statistical physics. In particular, the term "econophysics" was coined by him in the mid 1990s. He holds a Ph. D. in Physics from Harvard University.

Tobias Preis is a Research Assistant and Doctoral Candidate in Department of Physics at the Johannes Gutenberg University Mainz (Germany). He was elected to the Gutenberg Academy of Young Academics in 2009. He is also working for Artemis Capital Asset Management GmbH as Managing Director. Homepage: http://www.tobiaspreis.de

Bubble trouble

When a stock market rises unsustainably, it can create a financial bubble that sooner or later will burst. **Tobias Preis** and **H Eugene Stanley** examine whether concepts from physics can be used to create a law describing exactly how such crashes occur

Wild fluctuations in the stock prices and currency exchange rates of every country have had a huge impact on the world economy and the personal fortunes of millions of us over the last few years. These instabilities have also had another, perhaps unintended, consequence – of thrusting the academic discipline of "econophysics" firmly into the limelight. But does a field that involves applying the concepts of statistical physics to economics really have anything important to contribute to discussions about the current economic crisis? Yes – absolutely – because finding laws describing fluctuations is the essence of statistical physics.

Physicists are not, of course, the first people to apply statistics to economics, with mathematicians also having contributed to the field for many years. One of their first significant breakthroughs came in 1900 when Louis Bachelier, working under the tutelage of the great French mathematician Henri Poincaré, published a PhD thesis in which he analysed real financial data. Bachelier claimed that a histogram of the changes in share price (measured over any period of time) forms a bell-shaped curve known as a Gaussian function, with very large fluctuations essentially never occurring. In other words, he believed that the chances of a serious crash occurring are almost zero. Such serious crashes are indeed very rare, but when they do occur, their effects can be devastating.

The model associated with Bachelier is often referred to as the "random walk" or "drunkard's walk" because he assumed that stock prices go up or down randomly by an amount that has a characteristic value. In recent years, however, econophysicists have been able to get their hands on a staggering quantity of real-time financial data, including the price, volume and timestamp of every transaction of every stock you can think of. Thanks to this information, which is now available in huge finan-

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Preis will be giving a free online lecture at 4 p.m. BST on 12 May – see physicsworld.com/cws/channel/multimedia for more details

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