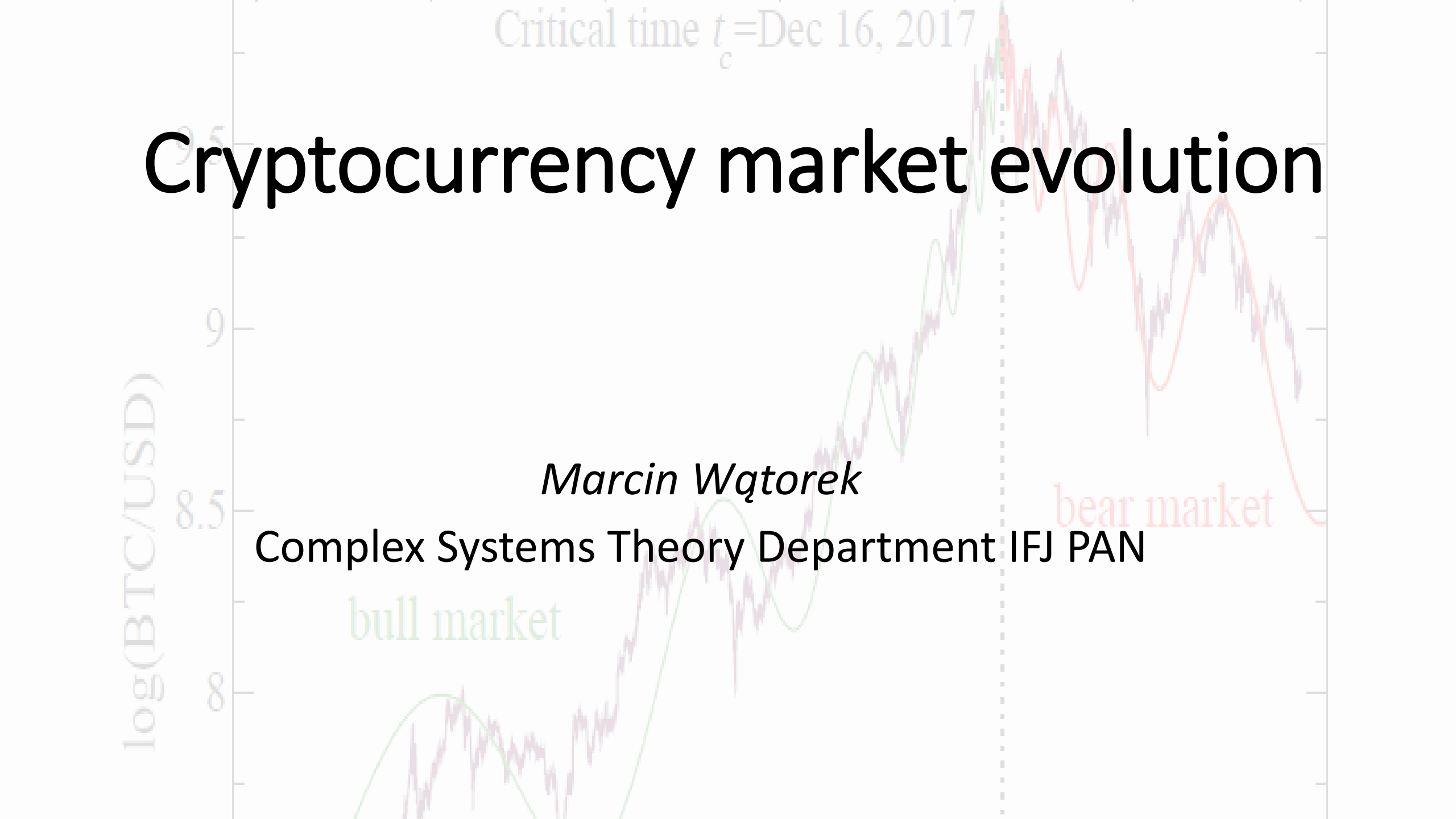
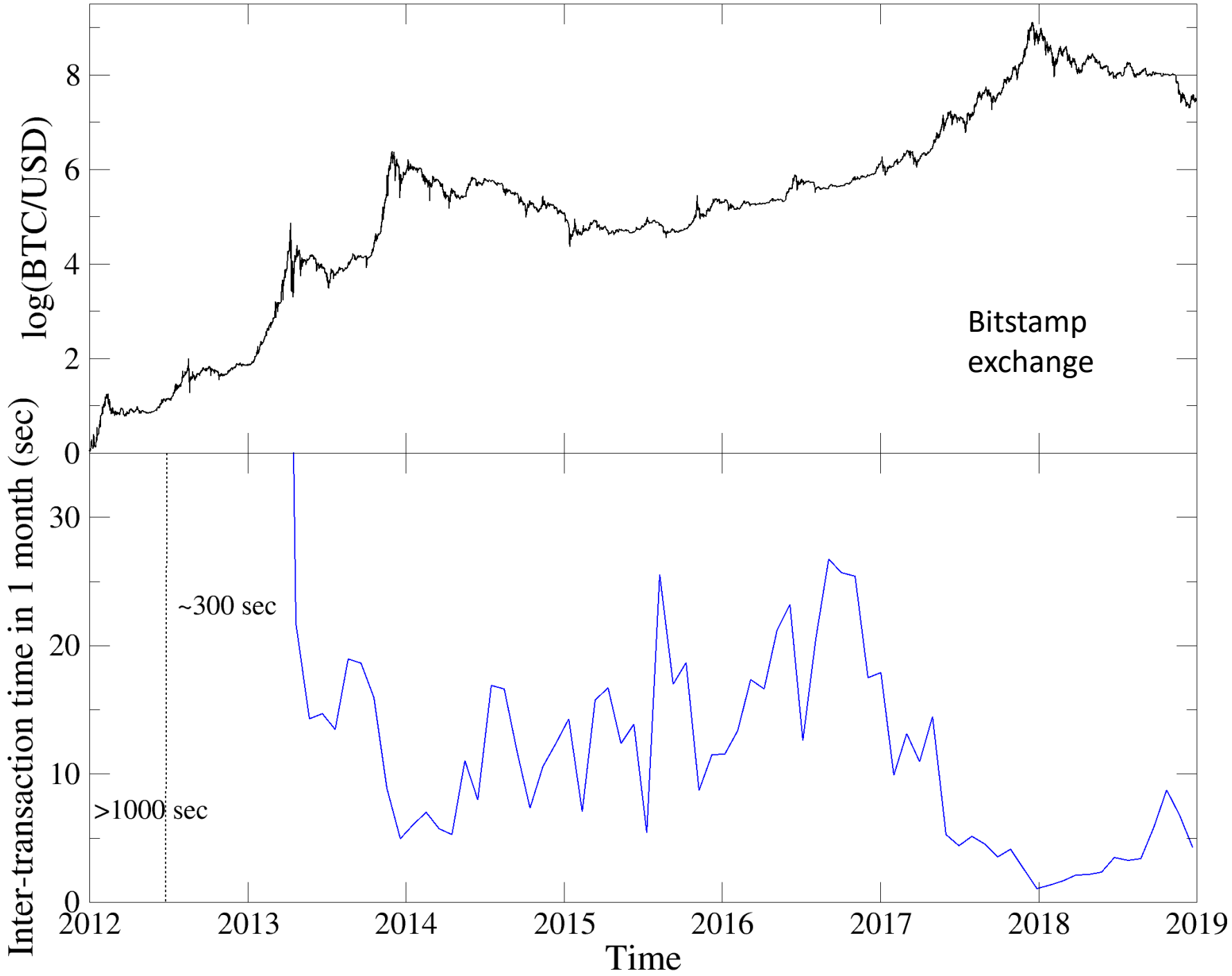
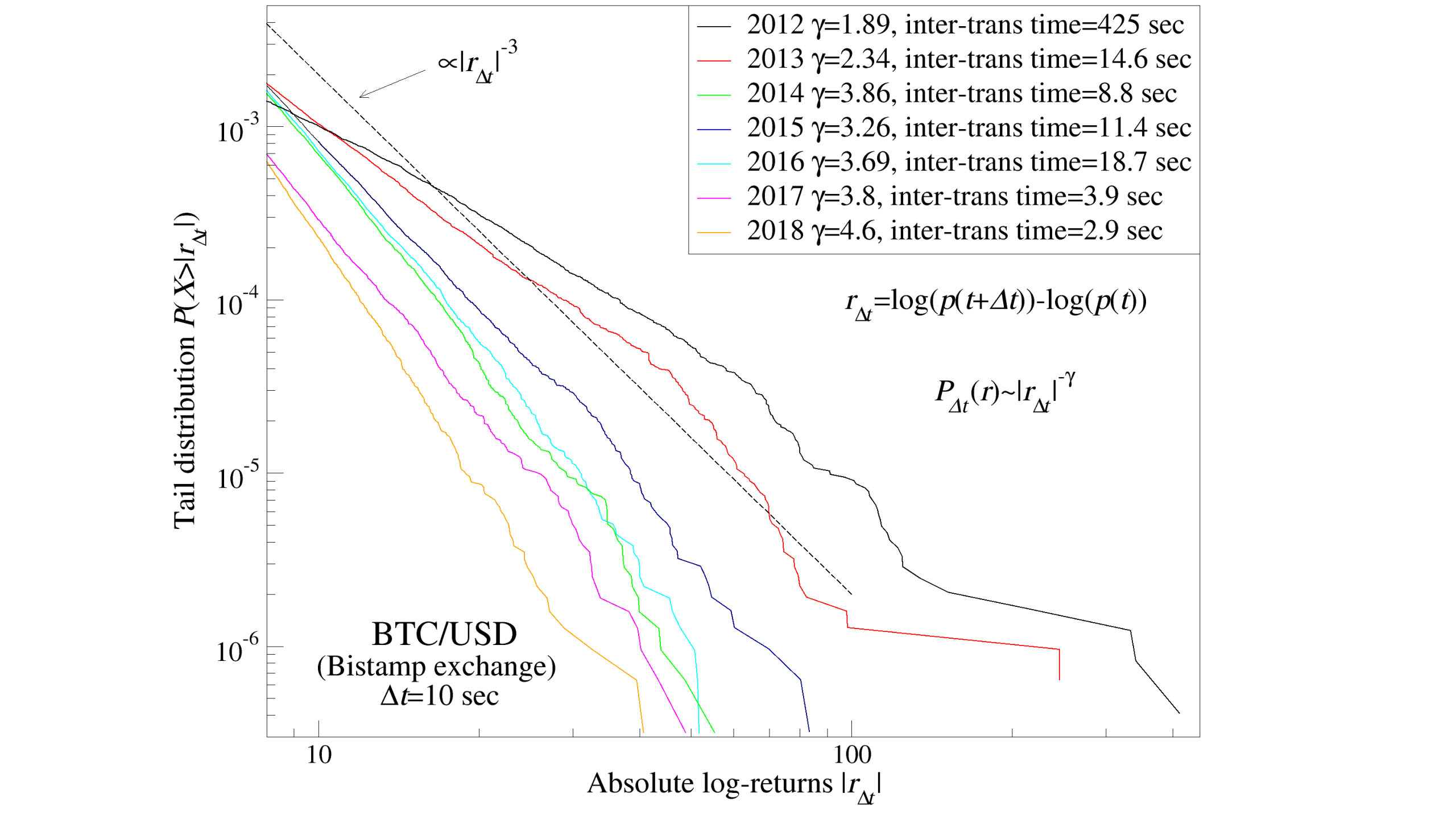


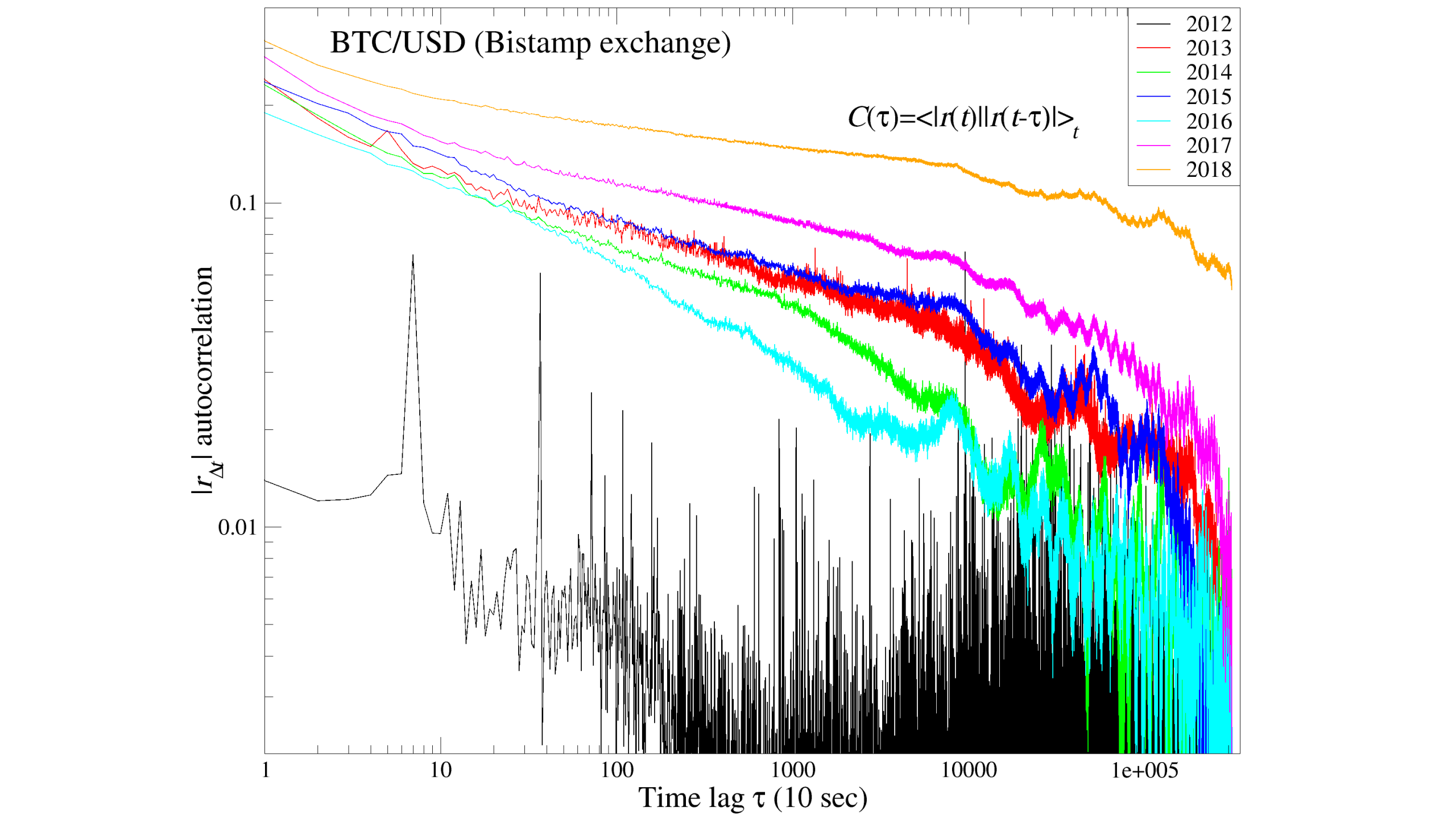
Cryptocurrency market evolution

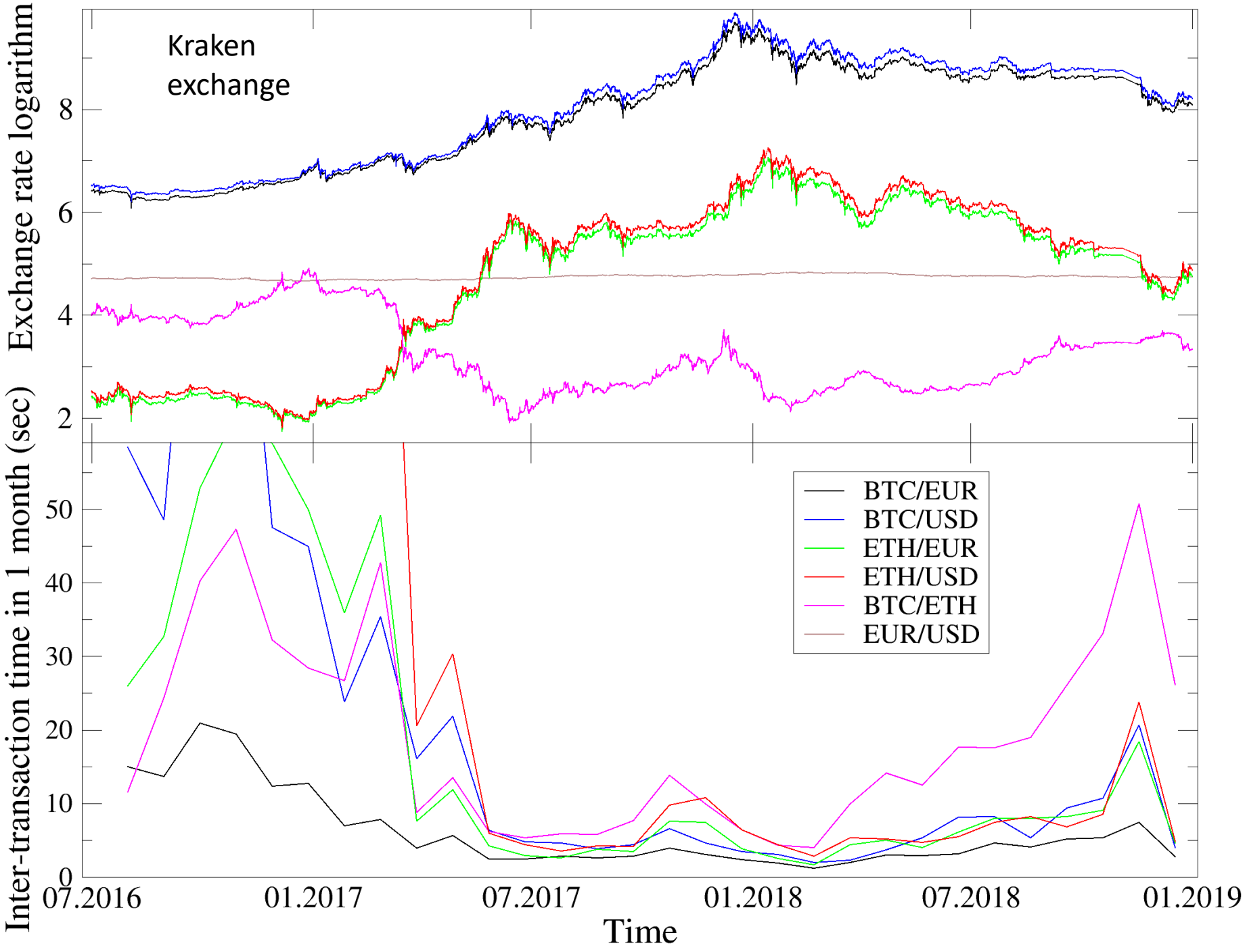
Marcin Wątorek

Complex Systems Theory Department IFJ PAN

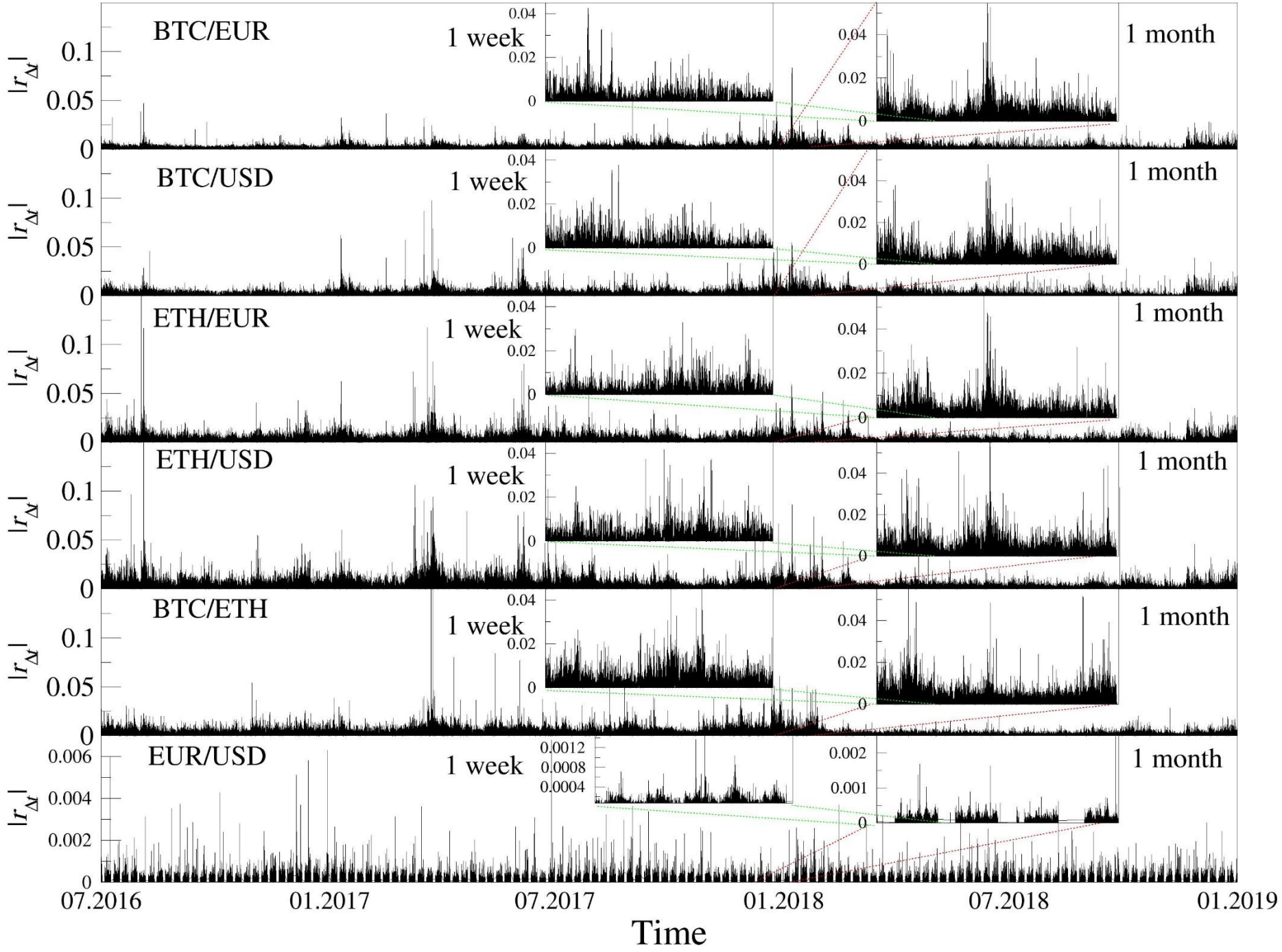

log(BTC/USD)
8
6
4
2
0
Bitstamp
exchange
Inter-transaction time in 1 month (sec)
30
20
10
0
~300 sec
>1000 sec
2012
2013
2014
2015
2016
2017
2018
2019
Time

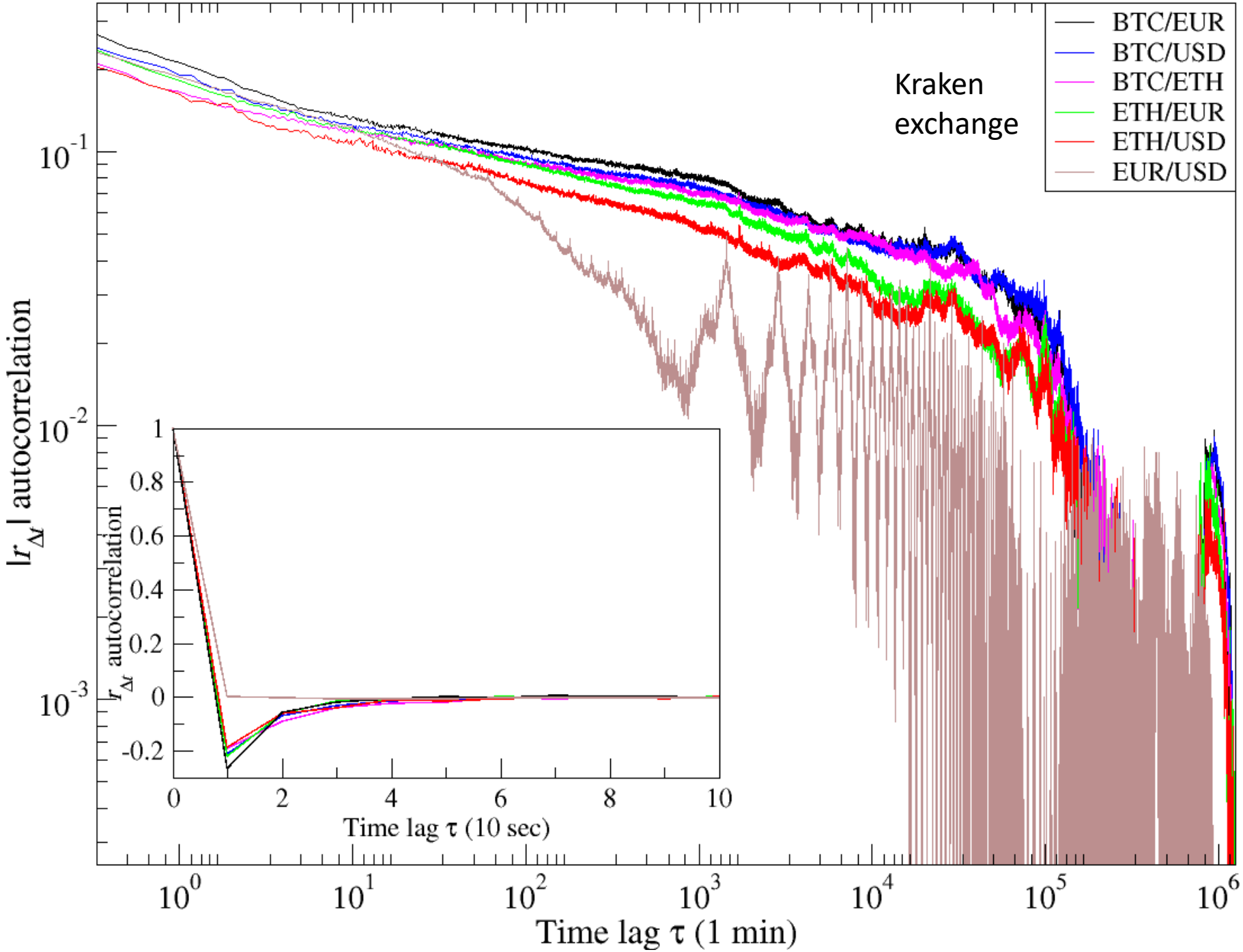

2012 γ=1.89, inter-trans time=425 sec
2013 γ=2.34, inter-trans time=14.6 sec
2014 γ=3.86, inter-trans time=8.8 sec
2015 γ=3.26, inter-trans time=11.4 sec
2016 γ=3.69, inter-trans time=18.7 sec
2017 γ=3.8, inter-trans time=3.9 sec
2018 γ=4.6, inter-trans time=2.9 sec
$\propto |r_{\Delta t}|^{-3}$
$r_{\Delta t}=\log(p(t+\Delta t))-\log(p(t))$
$P_{\Delta t}(r)\sim |r_{\Delta t}|^{-\gamma}$
BTC/USD
(Bistamp exchange)
Δt=10 sec
Tail distribution $P(X>|r_{\Delta t}|)$
Absolute log-returns $|r_{\Delta t}|$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10
100

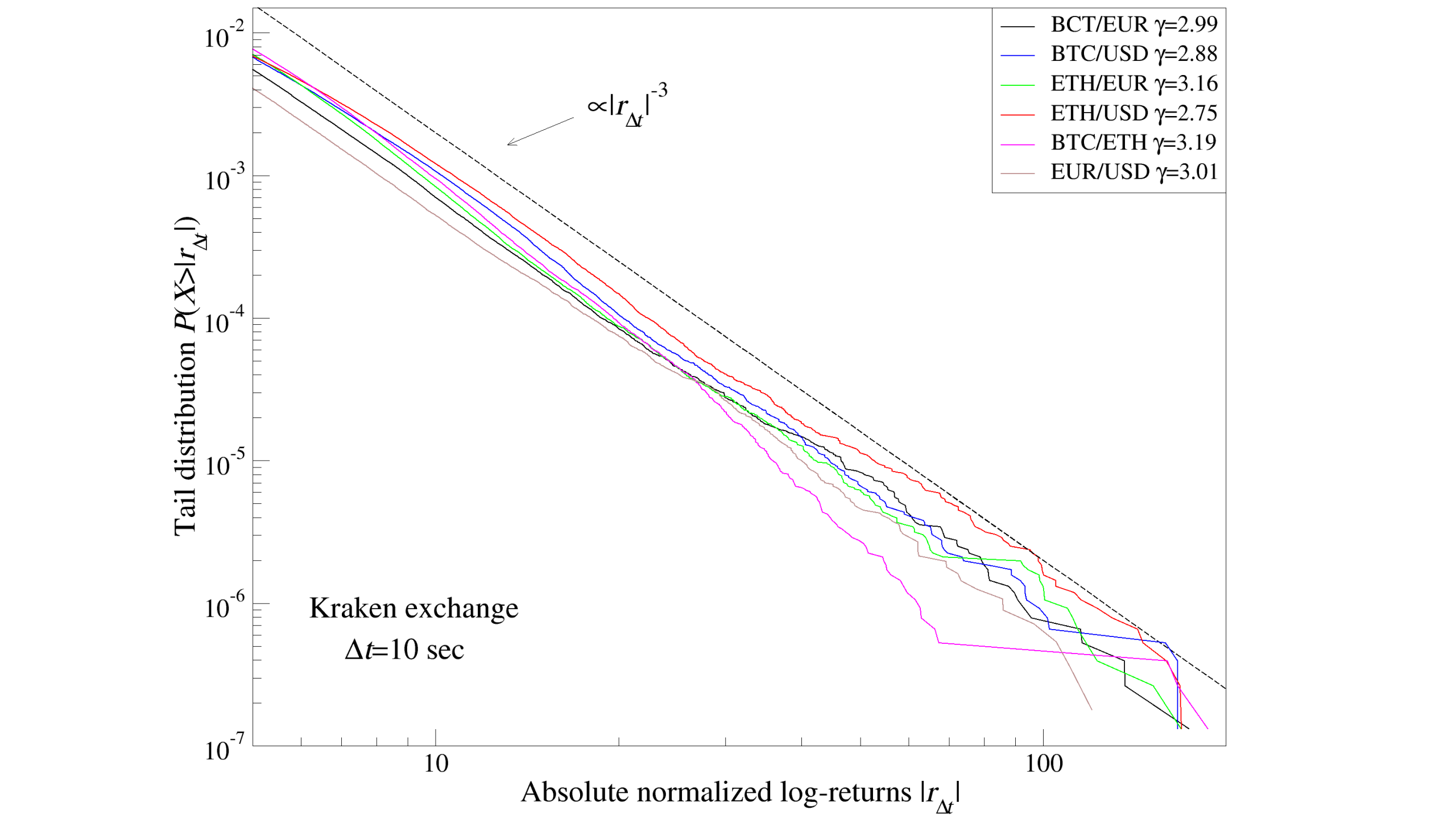

BTC/USD (Bistamp exchange)
$C(\tau)=<|r(t)||r(t-\tau)|>_t$
2012
2013
2014
2015
2016
2017
2018
0.1
0.01
$|r_{\Delta t}|$ autocorrelation
1
10
100
1000
10000
1e+005
Time lag τ (10 sec)


Kraken
exchange
Exchange rate logarithm
8
6
4
2
Inter-transaction time in 1 month (sec)
50
40
30
20
10
0
BTC/EUR
BTC/USD
ETH/EUR
ETH/USD
BTC/ETH
EUR/USD
07.2016
01.2017
07.2017
01.2018
07.2018
01.2019
Time

Kraken exchange




Kraken
exchange
BTC/EUR
BTC/USD
BTC/ETH
ETH/EUR
ETH/USD
EUR/USD
$|r_{\Delta t}|$ autocorrelation
10^{-1}
10^{-2}
10^{-3}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
Time lag τ (1 min)
$r_{\Delta t}$ autocorrelation
1
0.8
0.6
0.4
0.2
0
-0.2
0
2
4
6
8
10
Time lag τ (10 sec)


BCT/EUR γ=2.99
BTC/USD γ=2.88
ETH/EUR γ=3.16
ETH/USD γ=2.75
BTC/ETH γ=3.19
EUR/USD γ=3.01
$\propto |r_{\Delta t}|^{-3}$
Kraken exchange
Δt=10 sec
Tail distribution $P(X>|r_{\Delta t}|)$
Absolute normalized log-returns $|r_{\Delta t}|$
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10
100

Multifractal formalism - MFCCA

Detrending procedure $X_\nu(s,i) = \sum_{j=1}^{i} x(\nu s + j) - P^{(m)}_{X,s,\nu}(j)$

$$f^2_{XY}(s,\nu) = \frac{1}{s}\sum_{i=1}^{s} X_\nu(s,i)\,Y_\nu(s,i)$$

Covariance

$$F^q_{XY}(s) = \frac{1}{2M_s}\sum_{\nu=0}^{2M_s-1} \mathrm{sign}\left[f^2_{XY}(s,\nu)\right]\left|f^2_{XY}(s,\nu)\right|^{q/2}$$

$$F^q_{XY}(s)^{1/q} = F_{XY}(q,s) \sim s^{\lambda(q)}$$

Scaling exponent

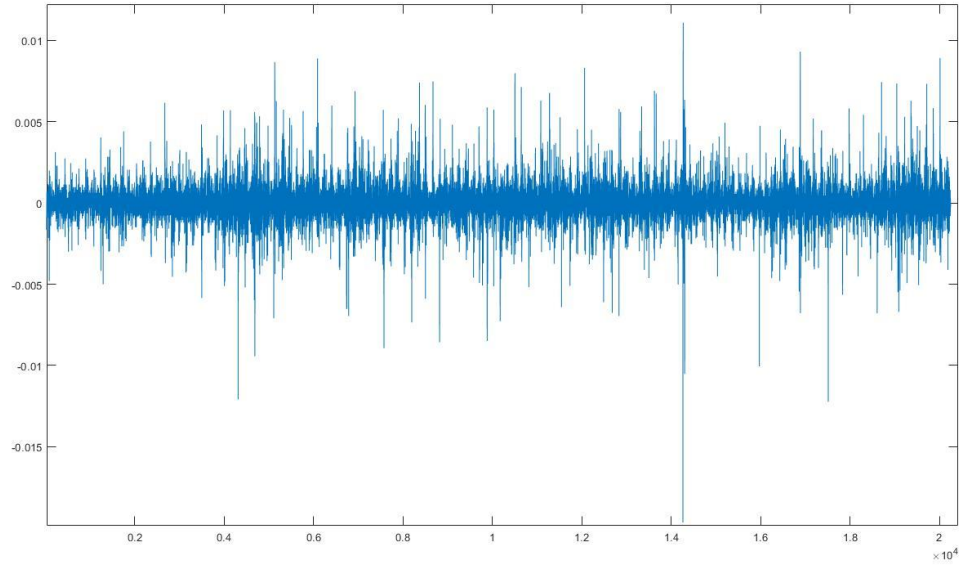
Cross-correlation function

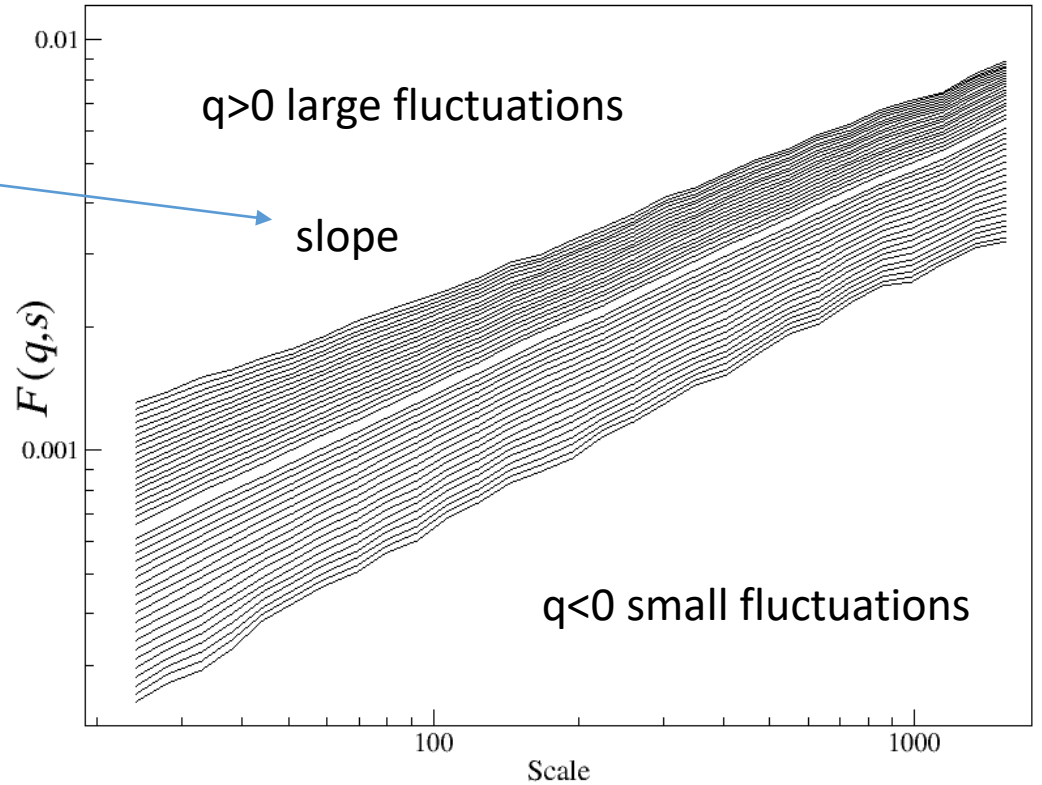
$$\rho_q(s) = \frac{F^q_{XY}(s)}{\sqrt{F^q_{XX}(s)F^q_{YY}(s)}}$$

Amplitude

Scale

Auto-correlation functions





Conventional MFDFA procedure

$$F_{ZZ}^{q}(s) = \frac{1}{2M_s} \sum_{\nu=0}^{2M_s-1} \left[f_{ZZ}^{2}(s,\nu) \right]^{q/2}$$

$$F_{ZZ}^{q}(s)^{1/q} = F_{ZZ}(q,s) \sim s^{h(q)}$$

Generalized Hurst exponent

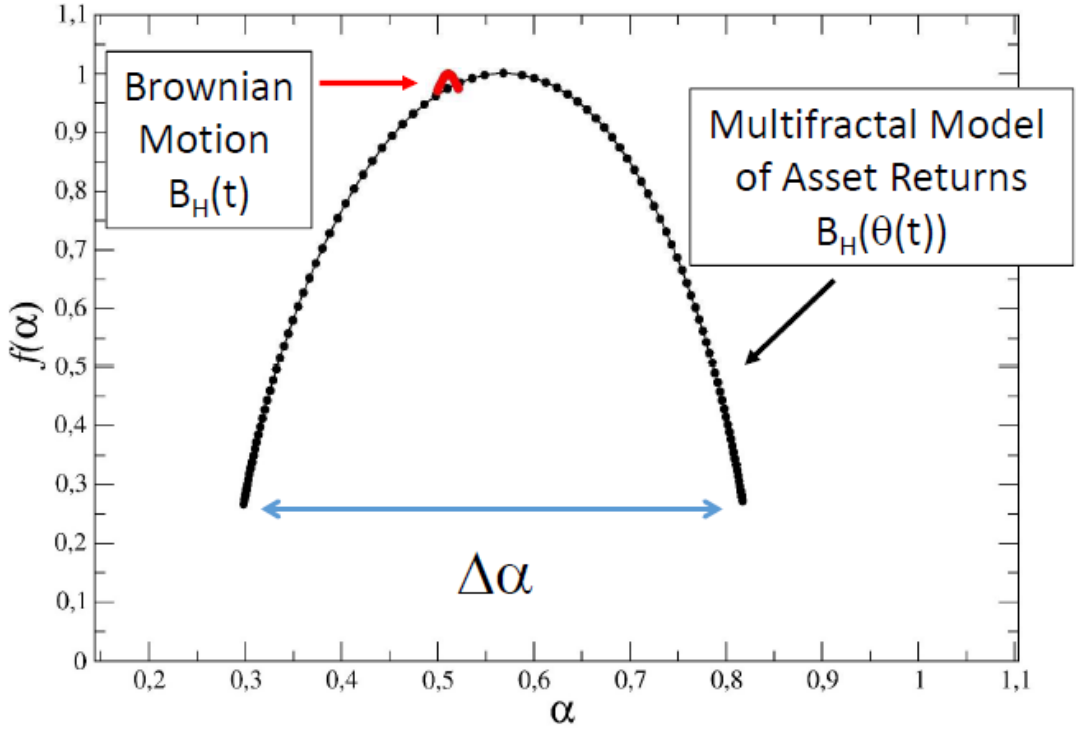
$$h_{xy}(q) = (h_x(q) + h_y(q))/2$$

average of generalized Hurst exponents

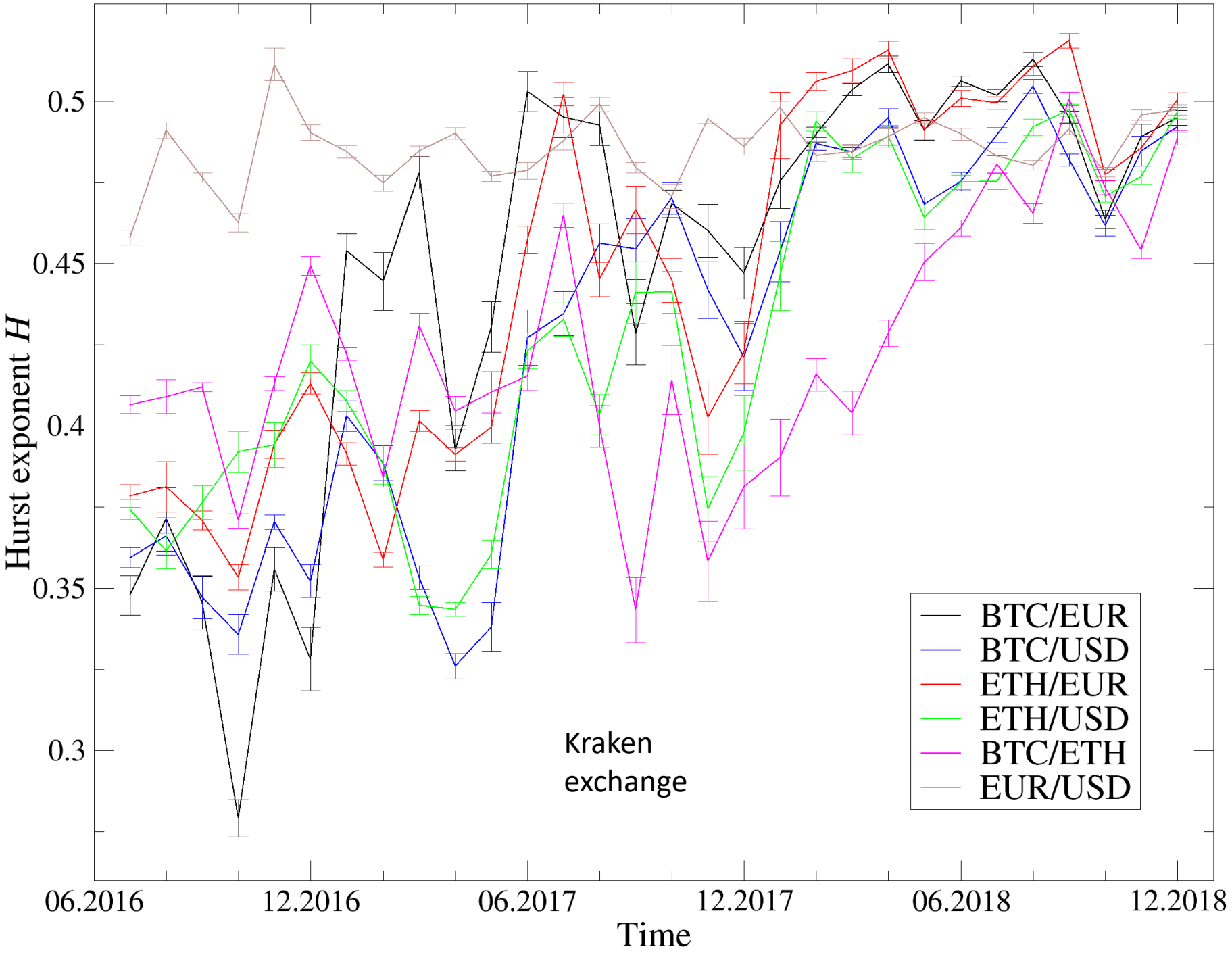
Singularity spectrum

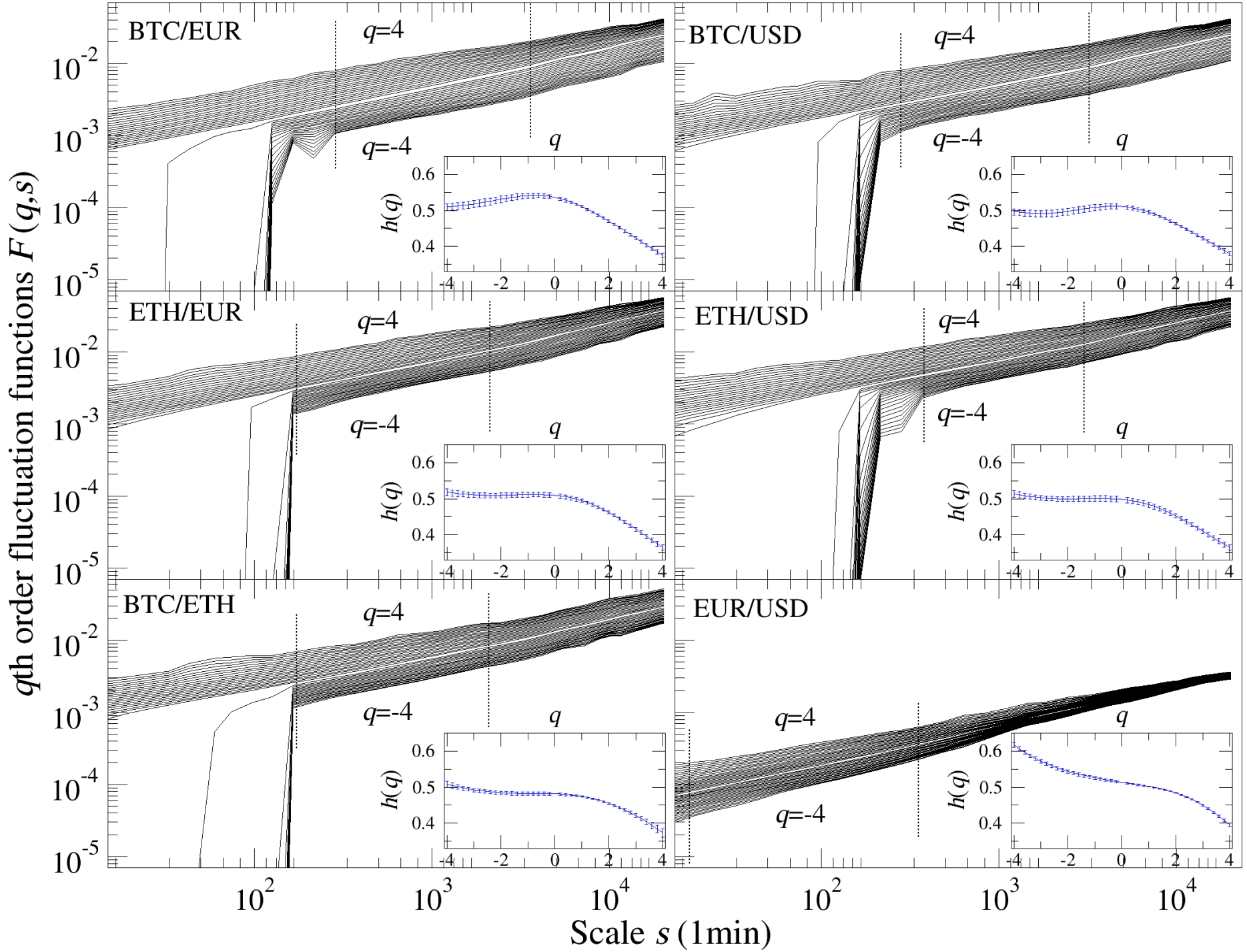
$$\tau(q) = qh(q) - 1$$

$$\alpha = \tau'(q) \quad \text{and} \quad f(\alpha) = q\alpha - \tau(q),$$

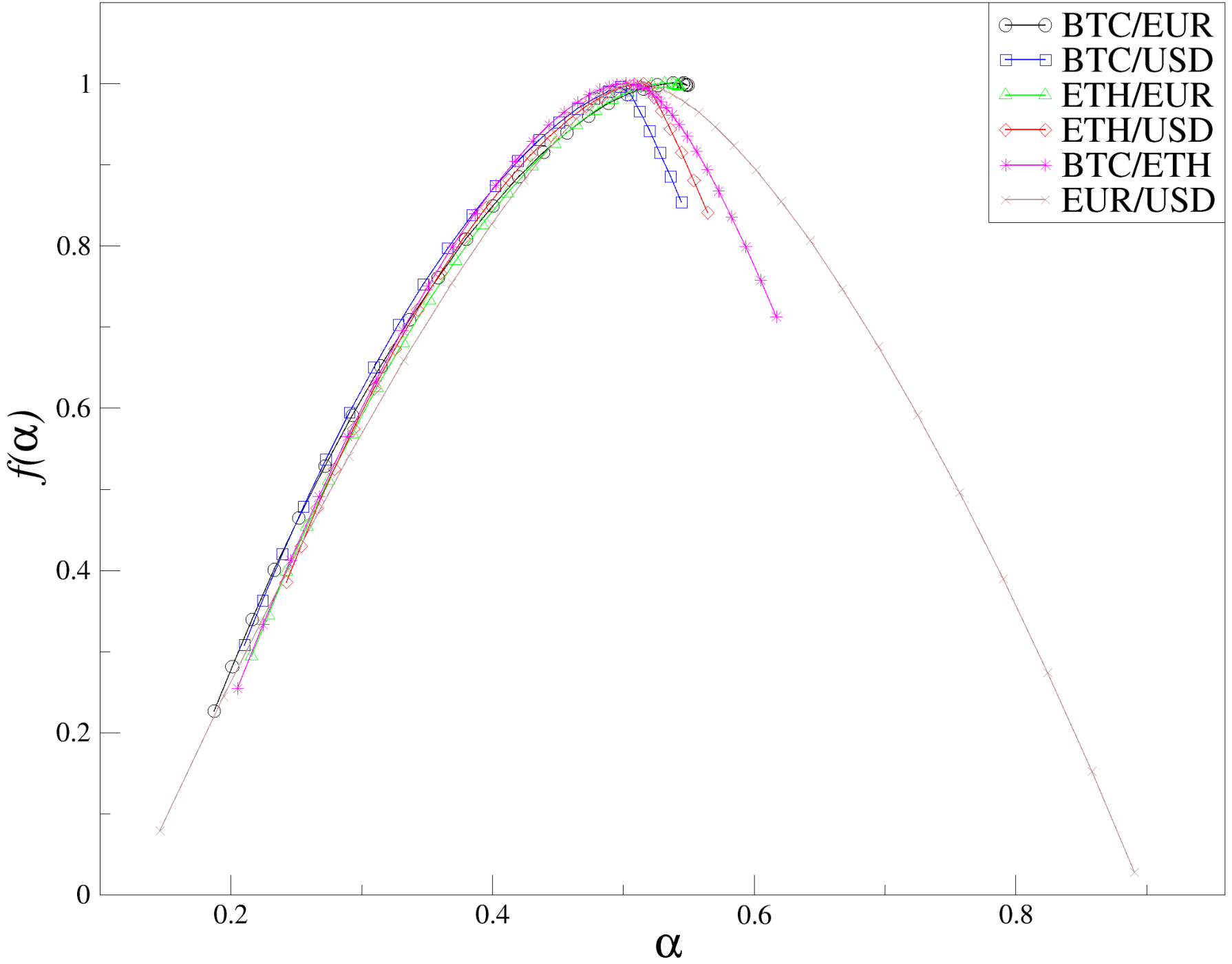


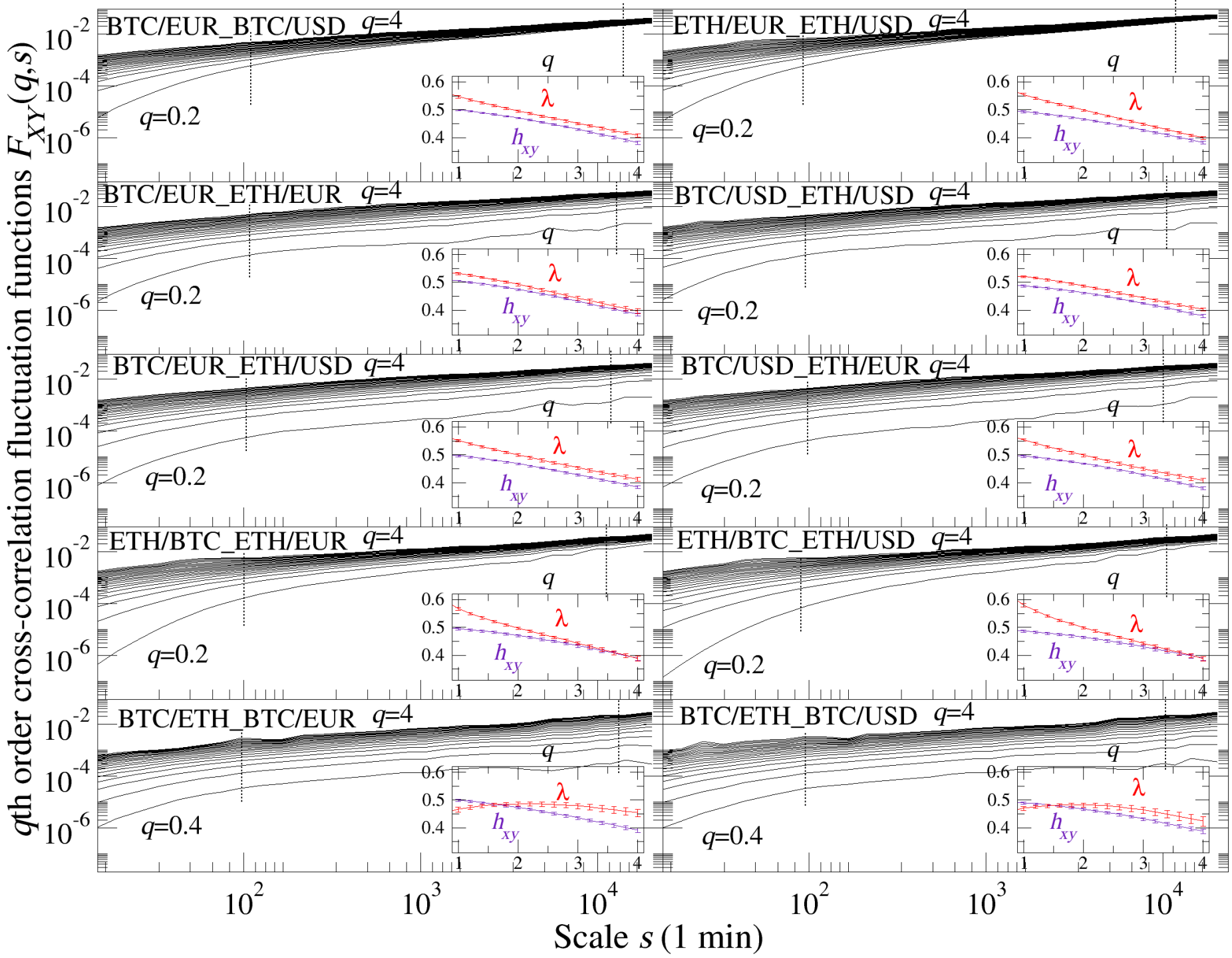
$$A_\alpha = (\Delta\alpha_L - \Delta\alpha_R)/(\Delta\alpha_L + \Delta\alpha_R),$$


0.5
0.45
0.4
0.35
0.3
Hurst exponent H
06.2016
12.2016
06.2017
12.2017
06.2018
12.2018
Time
Kraken
exchange
BTC/EUR
BTC/USD
ETH/EUR
ETH/USD
BTC/ETH
EUR/USD

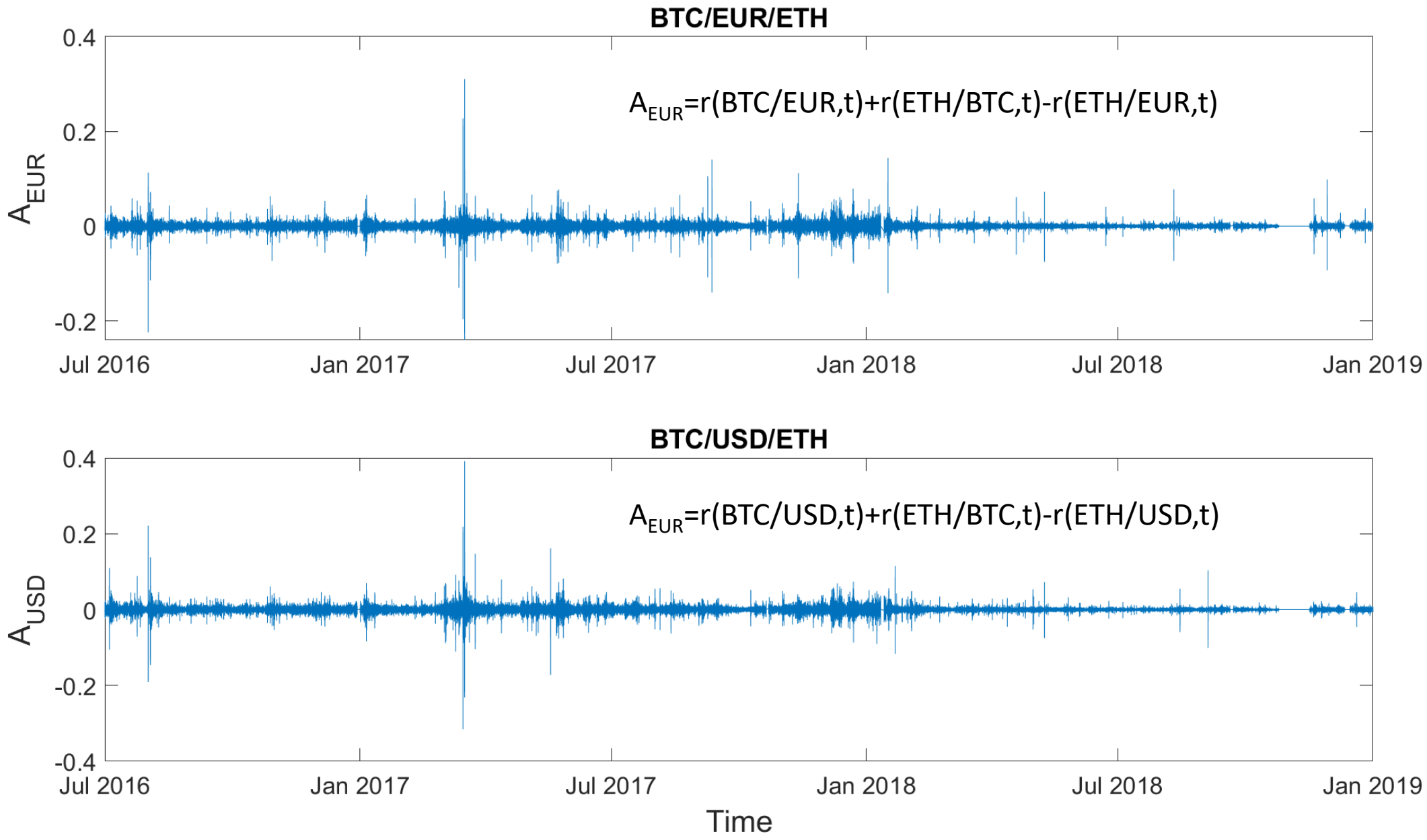

BTC/EUR
BTC/USD
ETH/EUR
ETH/USD
BTC/ETH
EUR/USD
q=4
q=-4
q
h(q)
qth order fluctuation functions F(q,s)
Scale s (1min)

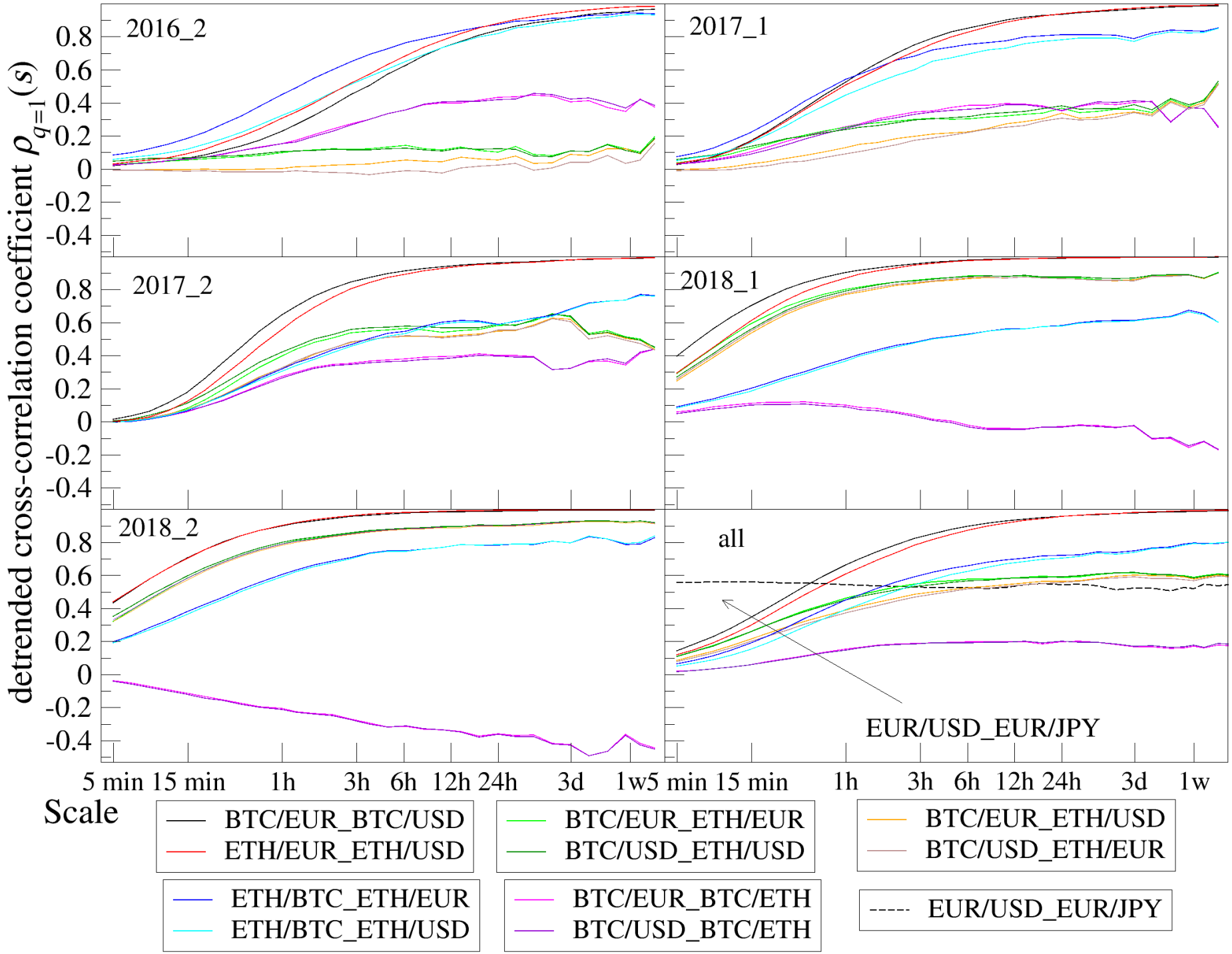
Kraken
exchange




BTC/EUR_BTC/USD q=4
ETH/EUR_ETH/USD q=4
BTC/EUR_ETH/EUR q=4
BTC/USD_ETH/USD q=4
BTC/EUR_ETH/USD q=4
BTC/USD_ETH/EUR q=4
ETH/BTC_ETH/EUR q=4
ETH/BTC_ETH/USD q=4
BTC/ETH_BTC/EUR q=4
BTC/ETH_BTC/USD q=4
q=0.2
q=0.4
q
λ
h_{xy}
qth order cross-correlation fluctuation functions $F_{XY}(q,s)$
Scale s (1 min)

Triangular arbitrage on Kraken exchange




2016_2
2017_1
2017_2
2018_1
2018_2
all
detrended cross-correlation coefficient $\rho_{q=1}(s)$
0.8
0.6
0.4
0.2
0
-0.2
-0.4
5 min
15 min
1h
3h
6h
12h
24h
3d
1w
Scale
BTC/EUR_BTC/USD
ETH/EUR_ETH/USD
BTC/EUR_ETH/EUR
BTC/USD_ETH/USD
BTC/EUR_ETH/USD
BTC/USD_ETH/EUR
ETH/BTC_ETH/EUR
ETH/BTC_ETH/USD
BTC/EUR_BTC/ETH
BTC/USD_BTC/ETH
EUR/USD_EUR/JPY

Conclusions

- Bitcoin market has recently and rapidly developed the statistical hallmarks which are empirically observed for all “mature” markets like stocks, commodities or Forex.
- It also appears that the maturity of the Bitcoin has cascaded onto other cryptocurrencies - ETH, leading to the emergence of a seemingly-independent world cryptocurrency market, akin to the foreign exchange.
- cryptocurrencies have already started developing multifractal cross-correlations, even when traded directly among themselves.
- Since high-frequency price data are available since the beginning of trading, cryptocurrencies offers a unique window into the statistical characteristics of a market maturation trajectory.
- The analysis of the detrended cross-correlation coefficients reveals a dependence on the time scales which may be caused by large arbitrage opportunities that occurred in the past. By the end of 2018, these opportunities have decreased significantly, making the cryptocurrency market more synchronized.

- S. Drożdż, R. Gębarowski, L. Minati, P. Oświęcimka, M. Wątorek, „Bitcoin market route to maturity? Evidence from return fluctuations,temporal correlations and multiscaling effects”, Chaos 28, 071101 (2018).
- S. Drożdż, L. Minati, P. Oświęcimka, M.Stanuszek, M. Wątorek „Signatures of cryptocurrency market decoupling from the Forex” arXiv:1906.07834 (2019).