

+ Code + Text

```
#Author: Neelakshi Joshi and Reinaldo Roberto Rosa
#Version: 1.0
#Date: 11/04/2018

import numpy as np
from matplotlib import pyplot

def pmodel(noValues=256, p=0.375, slope=[]):
    noOrders = int(np.ceil(np.log2(noValues)))
    noValuesGenerated = 2**noOrders

    y = np.array([1])
    for n in range(noOrders):
        y = next_step_1d(y, p)

    if (slope):
        fourierCoeff = fractal_spectrum_1d(noValues, slope/2)
        meanVal = np.mean(y)

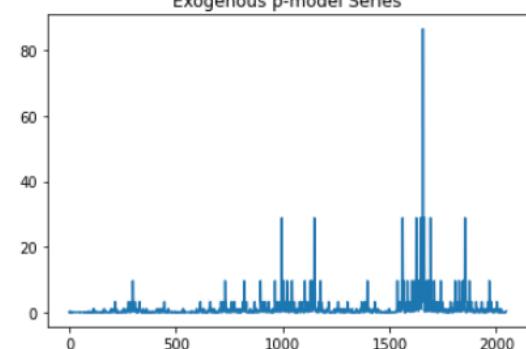
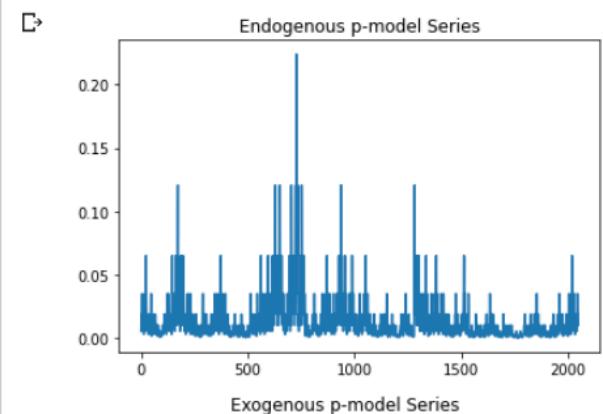
    return a
#Endogenous
x, y = pmodel (2048, 0.35, 0.45)
pyplot.plot(y/80)
pyplot.title("Endogenous p-model Series")
pyplot.show()

#Exogenous
x, y = pmodel (2048, 0.75, 0.75)
pyplot.plot(y)
pyplot.title("Exogenous p-model Series")
pyplot.show()
```

```
a[t4] = coeff
a[1] = 0

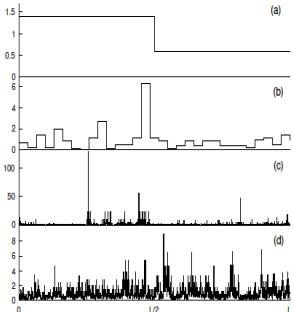
return a
#Endogenous
x, y = pmodel (2048, 0.35, 0.45)
pyplot.plot(y/80)
pyplot.title("Endogenous p-model Series")
pyplot.show()

#Exogenous
x, y = pmodel (2048, 0.75, 0.75)
pyplot.plot(y)
pyplot.title("Exogenous p-model Series")
pyplot.show()
```



## p-model: séries temporais com flutuações extremas provenientes de processos estocásticos

`pmodelstg.py`

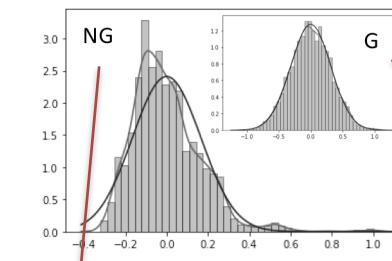
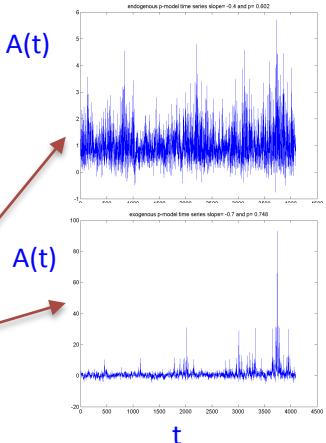


Input:

$$N=2^n,$$

$$p>0.50$$

$$0.3<\beta<0.5, \\ 0.5<\beta<0.9$$



$$PDF = f(A) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{A-\mu}{\sigma})^2}$$

$$\mu = \frac{1}{N} \sum_{i=1}^N A_i$$

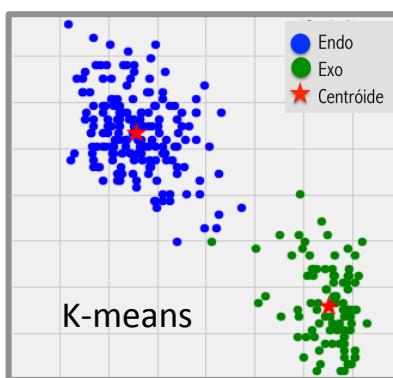
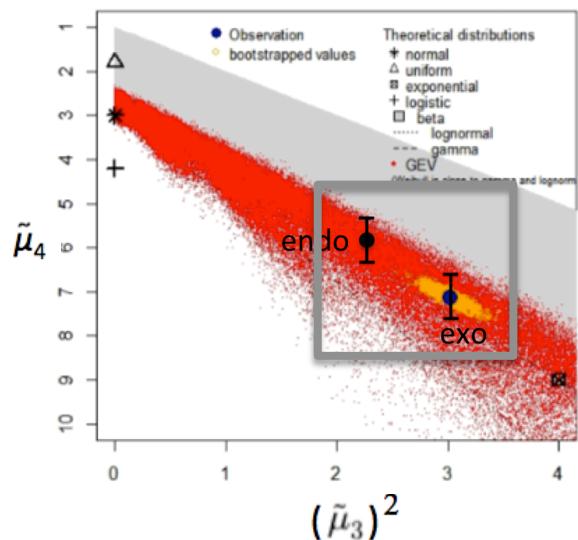
$$G_{(\xi,\sigma,\mu)}(A) = \begin{cases} 1 - \left(1 + \frac{\xi(A-\mu)}{\sigma}\right)^{-\frac{1}{\xi}} & p / \xi \neq 0 \\ 1 - \exp\left(-\frac{A-\mu}{\sigma}\right) & p / \xi = 0 \end{cases}$$

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (A_i - \mu)^2}$$

$\mu \in (-\infty, \infty)$  localização  
 $\sigma \in (0, \infty)$  escala  
 $\xi \in (-\infty, \infty)$  forma

Meneveau, C. and Sreenivasan, K. R.: Simple multifractal cascade model for fully developed turbulence, Phys. Rev. Lett., 59(13), 1424–1427, 1987.

Quais são e para que servem os tratamentos analíticos computacionais de natureza estatística para séries temporais com flutuações extremas?



## Statistical Moments (Pearson's Theory)

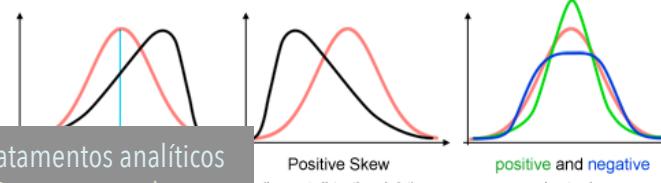
$$PDF = f(A) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{A-\mu}{\sigma})^2} \quad \sigma \equiv (\mathbb{E}[(A - \mu)^2])^{\frac{1}{2}}$$

$$\frac{\mu_n}{\sigma^n} = \frac{\mathbb{E}[(A - \mu)^n]}{\sigma^n}$$

$$\tilde{\mu}_3 = \mathbb{E}\left[\left(\frac{A-\mu}{\sigma}\right)^3\right] \\ = \frac{\mathbb{E}[A^3] - 3\mu\sigma^2 - \mu^3}{\sigma^3}$$

$$\tilde{\mu}_4 = \frac{\mu_4}{\sigma^4} = \frac{\mathbb{E}[(A - \mu)^4]}{(\mathbb{E}[(A - \mu)^2])^2}$$

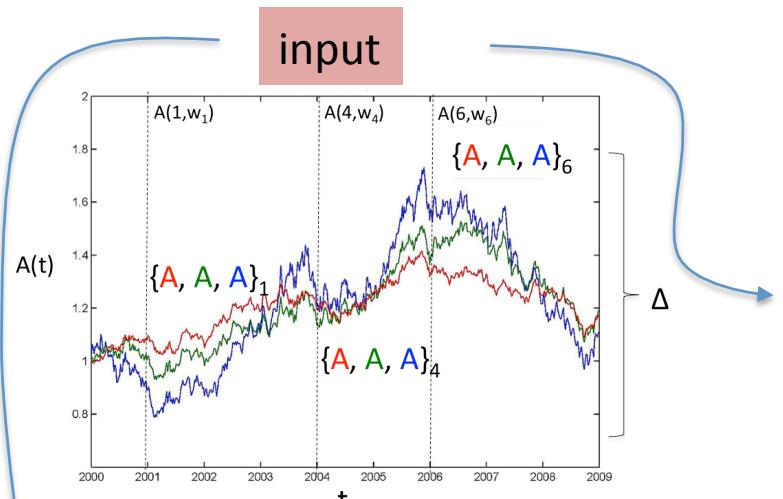
$$\tilde{\mu}_4 = \mathbb{E}\left[\left(\frac{A-\mu}{\sigma}\right)^4\right]$$



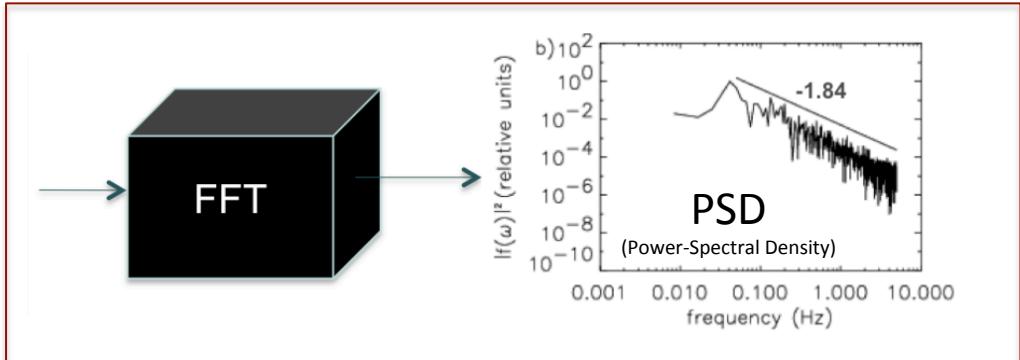
Quais são e para que servem os tratamentos analíticos computacionais de natureza estatística-espectral para séries temporais com flutuações extremas?

Quais são e para que servem os tratamentos analíticos computacionais de natureza espectral?

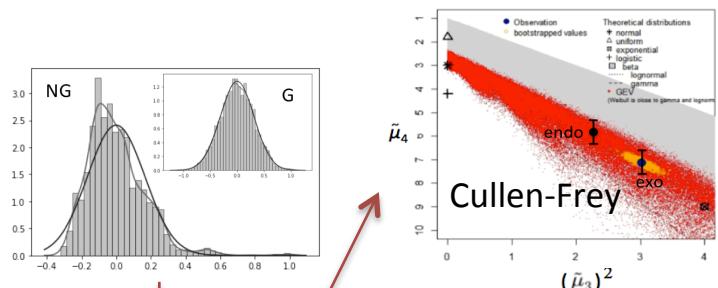
Quais são os modelos de natureza estatística mais adequados para caracterização e previsão de eventos extremos?



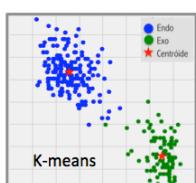
**Outputs**  
Caracterização Estatística-Espectral



**Outputs**  
Caracterização Estatística



Momentos



*Espectro de Singularidade (Singularity Spectra)*

$\alpha_H$  : Wavelet Transform Modulus Maxima (WTMM)

Halsey et al., PRA 33:1141, 1986; Arneodo et al.; Physica A 213:232, 1995.

**MFSS**

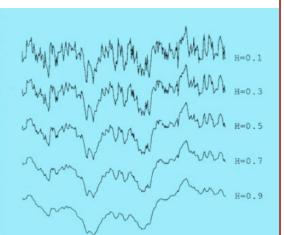
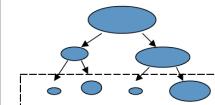
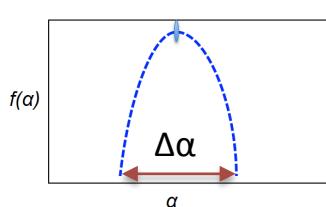
$$Z(s, q) = \sum_n |W_\psi I(s, t_n(s))|^q \approx s^{\tau(q)}$$

$$W_\psi [I](s, t_0) \approx s^{\alpha(t_0)}$$

→  $f(\alpha_H)$

"Singularity Spectrum"

where  $\alpha_H(t_0)$  is the Holder exponent (or singularity strength).

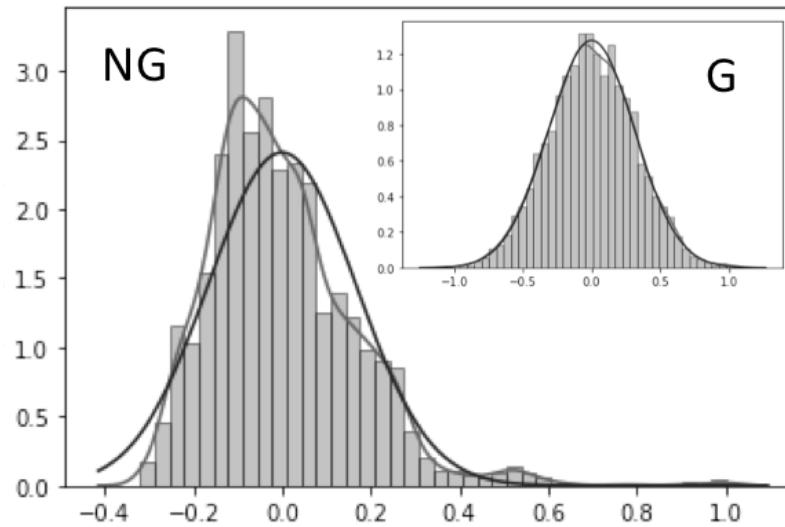


Inhomogeneous scaling process → spatiotemporal data

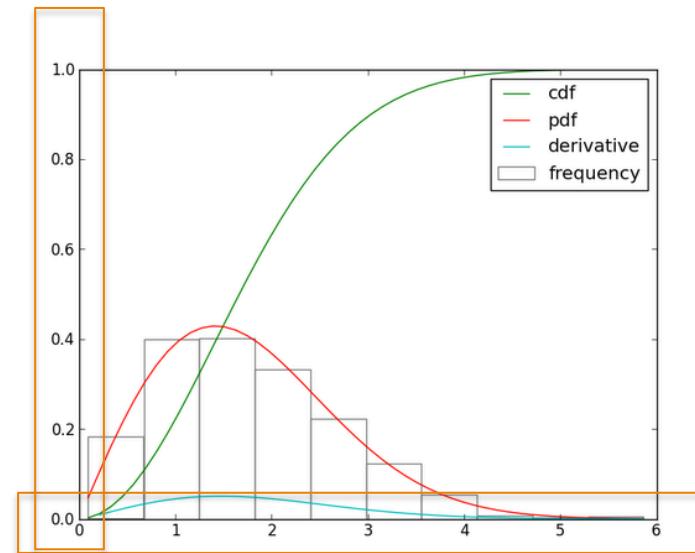
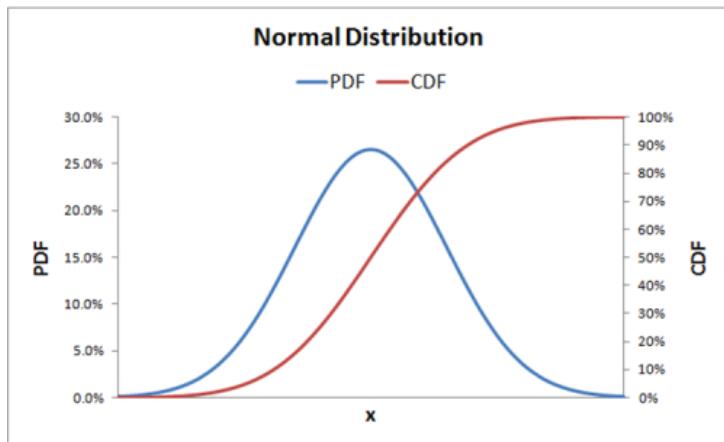
**Spatial Asymmetries**

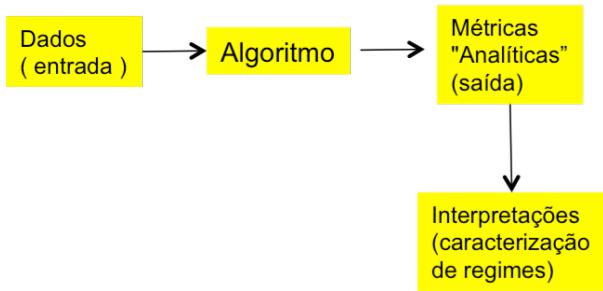
**PDF: Probability Density Function (Histogram → Function)**

**PDF: Probability Distribution Function (Function fitting Data)**



## Cumulative Distribution Function



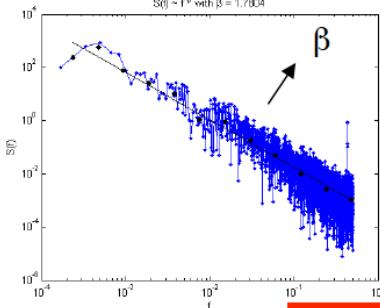


## Análise Espectral

Fundamental

Teorema de Wiener-Khinchin

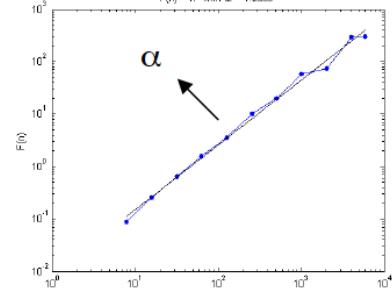
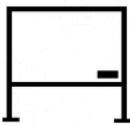
$$PSD = FFT [C(L)]$$



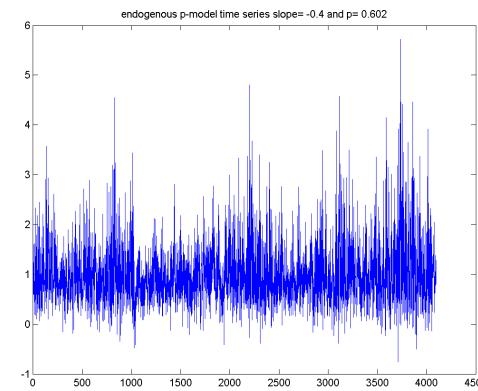
Avançada

Teorema de Parseval

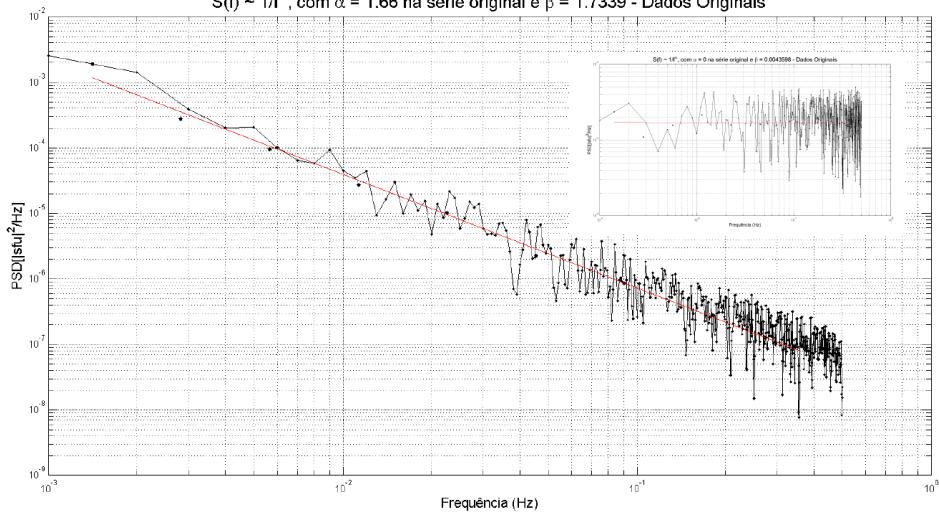
$$DFAS = FH [A(t)]$$



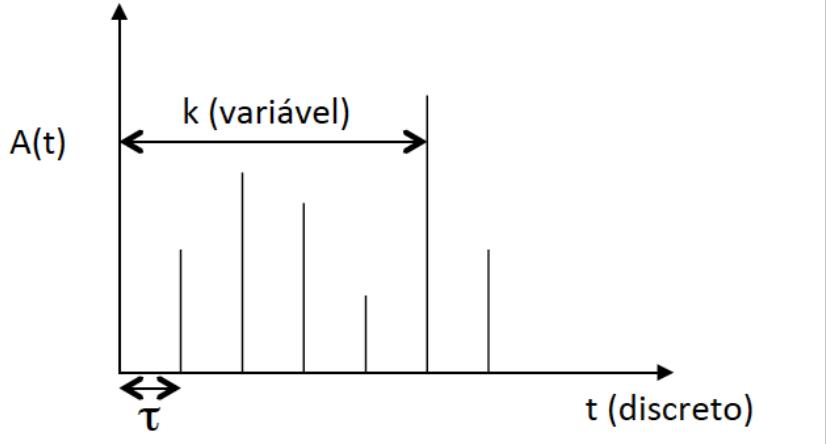
$$\alpha = (\beta + 1) / 2$$



$S(f) \sim 1/f^{\alpha}$ , com  $\alpha = 1.66$  na série original e  $\beta = 1.7339$  - Dados Originais



## Uniformização da Notação para Exponentes de Escalas em ST:



- $\tau$ : resolução da série
- $k$ : “lag” da Função de Auto-Correlação de  $A(t)$  com  $t=i$ :

$$C(k) = \frac{E[(A_i - \langle A \rangle)(A_{i+k} - \langle A \rangle)]}{\sigma^2}$$

$$C(k) \sim k^{-\gamma}$$

$$S(k) = |A(k)|^2$$

• D: Dimensão de Correlação [representa a dimensão do atrator no espaço  $A(t) \times A(t+k)$ ]

•  $\gamma$ : expoente da lei de escala para a função de auto-correlação de  $A(t)$

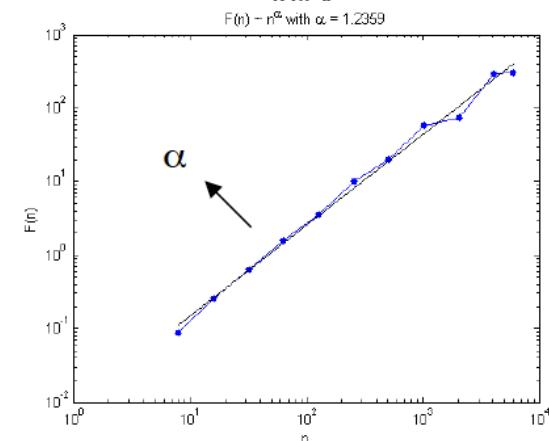
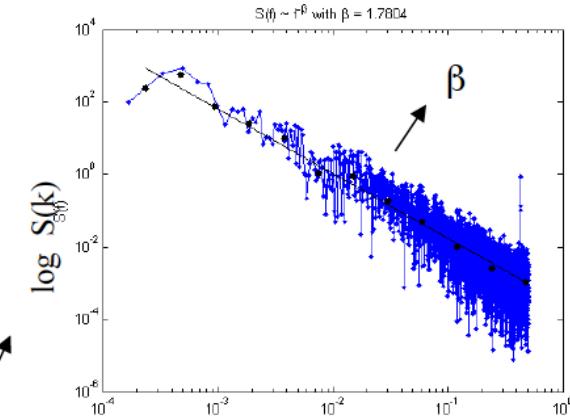
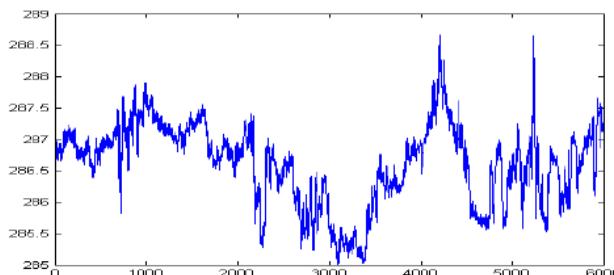
•  $S_q$ : função de estrutura de ordem  $q$  com  $S_q(k) = \langle |A(i+k) - A(k)|^q \rangle \sim k^{H(q)}$

•  $H(q)$ : Expoente de Hurst ou Expoente de Holder

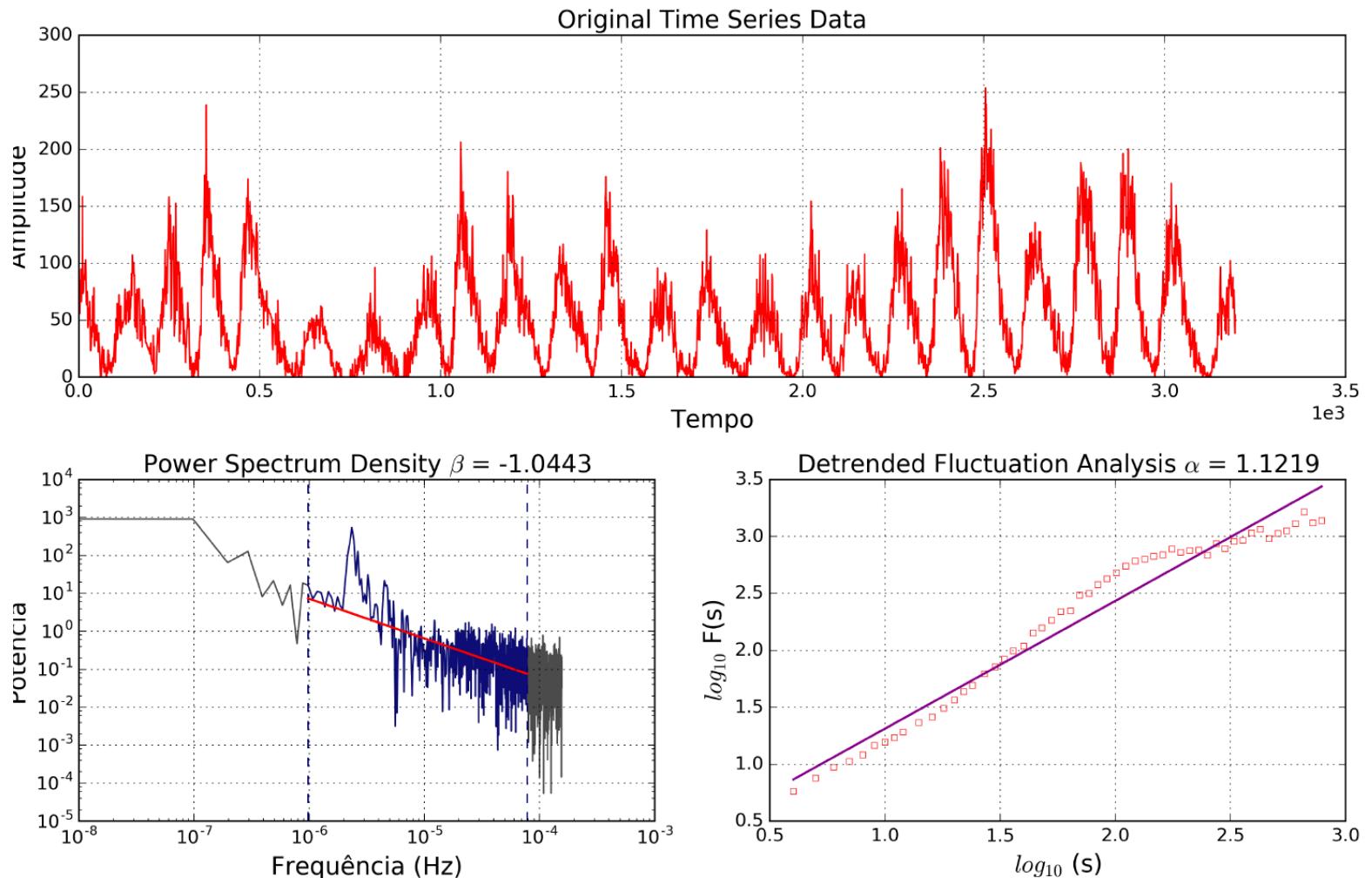
•  $\beta$ : expoente para espectro da ST original

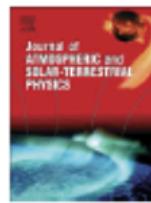
$$S(k) \sim k^{1/\beta}$$

•  $\alpha$ : expoente para espectro da ST “destendenciada” (estacionária)



## Algoritmo em Python: specplus.py





## Fluctuation analysis of solar radio bursts associated with geoeffective X-class flares $\star$

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### ABSTRACT

High temporal resolution solar observations in the decimetric range provide information on solar active regions dynamics and the occurrence of geoeffective events as flares and coronal mass ejections. We analyzed three geoeffective eruptive phenomena observed by the Space Weather Observatory radiometer. We have selected three decimetric bursts associated to X-class flares. The geomagnetic activity is also reported by the automatic monitoring system. Our results show that the DFA scaling exponent, scanning the SRB time series, can be used to study the importance of DFA in the context of solar eruptions.

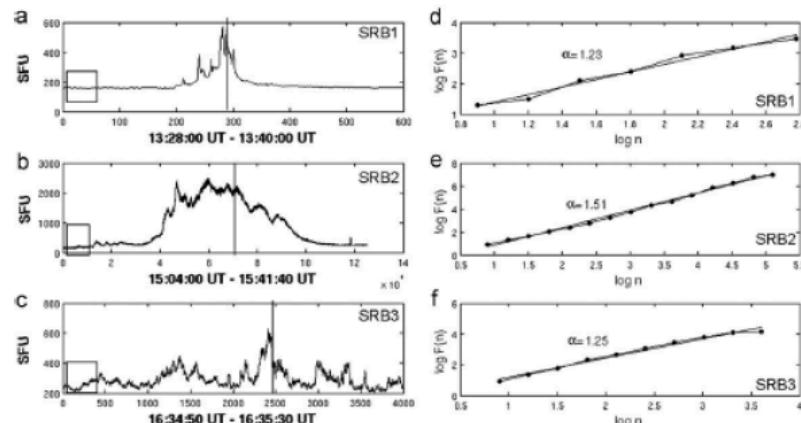


Fig. 3. The time profile of SRB1 (a), SRB2 (b) and SRB3 (c) showing the respective DFA scaling exponents in (d), (e) and (f).

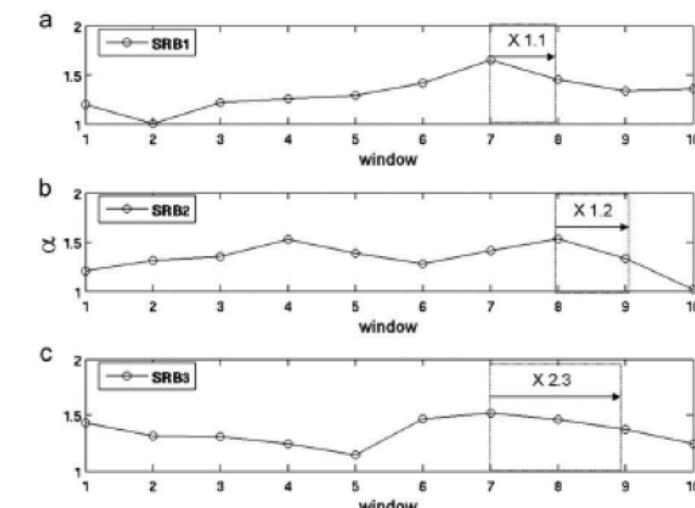
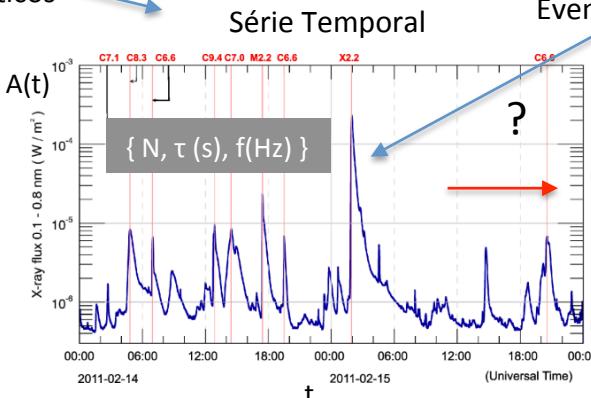


Fig. 4. Evolution of  $\alpha$  for each SRB before starting the correspondent flare. In each curve is shown a box indicating the window(s)—time interval—where the flare occurs.

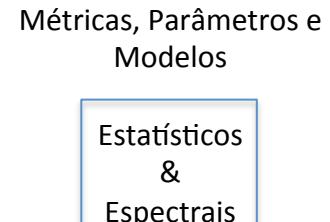
## Processos Estocásticos



## Eventos Extremos

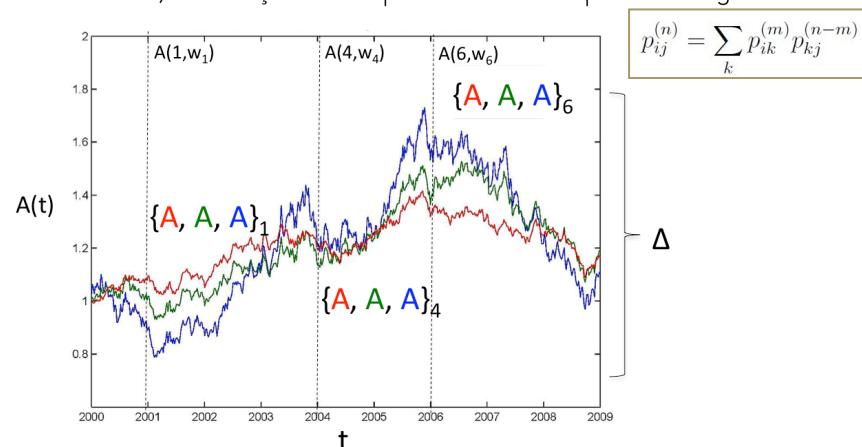


## “Caracterização”



### Noção de Processo Estocástico

Um processo estocástico  $S$  é uma sequência de variáveis aleatórias definidas sobre o mesmo **espaço de probabilidades** existindo  $p_j = p_i$  quando  $t \rightarrow \infty$ , sendo  $p$  a distribuição de probabilidades do ensemble (janela  $\Delta$  no Domínio de flutuação estocástica  $\mathcal{A}$ ) | a condição de Compatibilidade de Chapman-Kolmogorov ocorre:

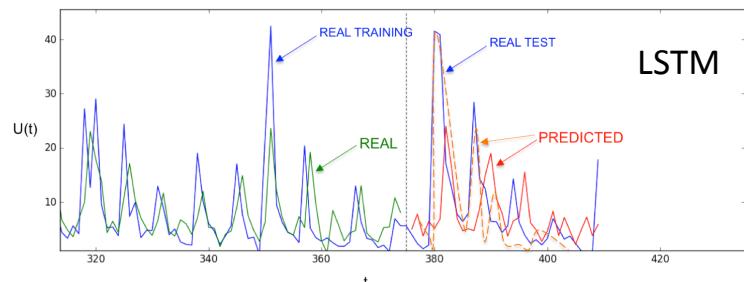


**Def.:** Um processo estocástico  $\{A(t) | t \in I\}_c$  é uma família/sequência de variáveis aleatórias  $A(t)$  distribuídas em  $\mathcal{A}$  que descreve a evolução da flutuação de  $A(t)$  e as suas características estatísticas ( $C$ ) que podem permanecer ou não constantes ao longo do tempo  $t \in I$ .  
**Exemplos de  $C$ :** Momentos, PDF e Espectros de Potência. Quando  $C$  não varia para toda a família, dizemos que a mesma pertence a uma classe de universalidade (exemplos: ruídos  $1/f^\beta$ , turbulência, processos caóticos, etc.).



### Conteúdo das Nossas Aulas

1. O que é um processo estocástico? **05/5**
2. O que são eventos extremos em séries temporais? **11/5**
3. Quais são e para que servem os tratamentos analíticos computacionais de natureza estatística? **12/5**
4. Quais são e para que servem os tratamentos analíticos computacionais de natureza espectral? **20/5**
5. Quais são os modelos de natureza estatística mais adequados para caracterização e previsão de eventos extremos? **21/5**

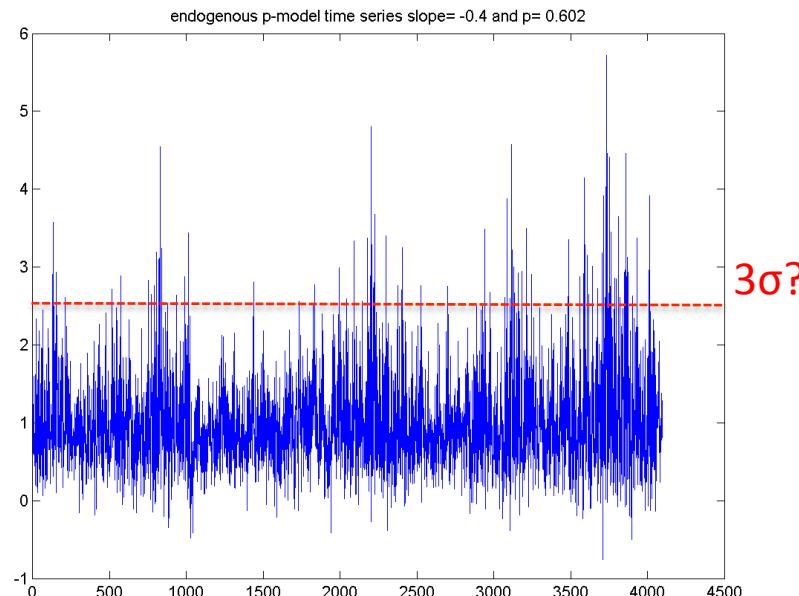


# Hands-On1-2022

Considere o material depositado no googledrive e

Steps 01 e 02:

Identifique  $3\sigma$  e gerar uma segunda ST (para cada caso) sem os valores  $>3\sigma$



Steps 03 e 04:

Obter Histograma com ajuste e os respectivos valores de K e  $S^2$  para cada uma das 4series

Step 5:

Plotar os valores num espaço K x  $S^2$

