Time series analysis- an introduction to advanced methods

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Aim: This course will introduce the basic ideas underlying a broad range of modern time series analysis techniques in the context of physical processes and measurement constraints.

Outcome: to be able to quantify properties of physical timeseries and understand the impact of issues such as data gaps, non uniform sampling rate and experimental uncertainties.

As well as formal lectures this course will use tutorial material provided by Matlab (including Signal Processing and Wavelets toolboxes), and students are strongly encouraged to use Matlab for the assessed work.

Syllabus: to be delivered in 3 blocks of 4 hours.

Block 1: Fourier methods. Revision of Fourier theory and introduction to discrete Fourier transforms. Windowing and spectral leakage. Methods for amplitude and phase spectra in 'real' signals- noise, nonuniform sampling in time and data gaps. Error estimates for power spectral density. Auto and cross correlation. Time stationarity.

Block 2: Higher order spectra and Wavelets. Bicoherence, Tricoherence. Wavelets to estimate spectral properties and as tools to decompose, detrend and denoise signals. Orthogonal and non- orthogonal bases and more general transforms, Single Value Decomposition (Principal Component Analysis).

Block 3: Higher Order Methods and nonlinear processes. Introduction to fractal and multifractal scaling. Methods to quantify scaling- Generalized Structure Functions and Probability Density Function collapse- relationship to Stochastic Differential Equation models. Dealing with finite size effects- uncertainties and outliers. Methods based on thresholding: Burst distributions and waiting times, delay plots. Mutual Information.

The module will be assessed with an extended worked example- students will be expected to apply a subset of the above ideas to a (provided) physical datasets and to write a short report on their results.

Course texts:

Bracewell, The Fourier Transform and its Applications 2nd Ed McGraw Hill
Kantz and Schreiber, Nonlinear time series analysis, 2nd ed, CUP
Percival and Walden, Spectral analysis for physical applications, CUP
Percival and Walden, Wavelet methods for time series analysis, CUP
Sornette, Critical Phenomena, 2nd ed Springer
Sethna, Entropy, order parameters and complexity, OUP