# Arbitrary-order Hilbert spectral analysis for time series possessing scaling statistics: a comparison study with detrended fluctuation analysis and wavelet leaders

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In this paper we present an extended version of Hilbert-Huang transform, namely arbitrary-order Hilbert spectral analysis, to characterize the scale-invariant properties of a time series directly in an amplitude-frequency space. We first show numerically that due to a nonlinear distortion, traditional methods require high-order harmonic components to represent nonlinear processes, except for the Hilbert-based method. This will lead to an artificial energy flux from the low-frequency (large scale) to the high-frequency (small scale) part. Thus the power law, if it exists, is contaminated. We then compare the Hilbert method with structure functions (SF), detrended fluctuation analysis (DFA), and wavelet leader (WL) by analyzing fractional Brownian motion and synthesized multifractal time series. For the former simulation, we find that all methods provide comparable results. For the latter simulation, we perform simulations with an intermittent parameter {\mu} = 0.15. We find that the SF underestimates scaling exponent when q > 3. The Hilbert method provides a slight underestimation when q > 5. However, both DFA and WL overestimate the scaling exponents when q > 5. It seems that Hilbert and DFA methods provide better singularity spectra than SF and WL. We finally apply all methods to a passive scalar (temperature) data obtained from a jet experiment with a Taylor's microscale Reynolds number Relambda \simeq 250. Due to the presence of strong ramp-cliff structures, the SF fails to detect the power law behavior. For the traditional method, the ramp-cliff structure causes a serious artificial energy flux from the low-frequency (large scale) to the high-frequency (small scale) part. Thus DFA and WL underestimate the scaling exponents. However, the Hilbert method provides scaling exponents {\xi}{\theta}(q) quite close to the one for longitudinal velocity.

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