Using Empirical mode decomposition and Hilbert spectral analysis to extract multifractal exponents

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Empirical Mode Decomposition (EMD, or Hilbert-Huang Transform, HHT) was introduced by Norden E. Huang about ten years ago. It is an alternative time-frequency analysis method with very local ability both in physical domain and frequency domain. In this talk, we will propose a new method, namely arbitrary order Hilbert spectral analysis (HSA), to characterize the scale invariant intermittency of a time series directly in amplitude-frequency space (Huang, *et al.* 2008). This method is an extended version of EMD. It provides an interesting information of the joint amplitude-frequency pdf $p(\omega,A)$, where ω is the so-called instantaneous frequency, and A is the amplitude. We first validate and verify the new method by considering the fractional Brownian motion simulation and a synthesized multifractal velocity field to show its usefulness for extracting the scaling exponent from monofractal and multifractal time series. We then compare the periodic effects both on structure function and the HSA approach to show that the former is strongly influenced by the periodic component and the latter one can constrain such effects in 0.3 decade. We finally apply this new method to a time series of homogeneous turbulence. The database we consider here is obtained from measurements of nearly isotropic turbulence, which is generated by an active-grid technique. The experiment is characterized by the Taylor-based Reynolds number $Re_\lambda=720$ (Kang et al. JFM 2003). It is found that the joint amplitude-frequency pdf has a scaling trend. Furthermore, the skeleton of this joint pdf also demonstrates power law behaviour with scaling exponents close to Kolmogorov's value. The second moment of this pdf provides the power spectrum in Hilbert space: we compare Fourier and Hilbert power spectra and show that both display a -5/3 spectrum in the inertial range. We then characterize intermittency properties by considering the marginal moments of the amplitude. We recover the classical structure function scaling exponents $\zeta(q)$ for the first time in the frequency space by using arbitrary order Hilbert marginal spectrum.

Reference

Huang Y.X., Schmitt F. G., Lu Z.M. And Liu Y.L. An amplitude-frequency study of turbulent scaling intermittency using Hilbert spectral analysis *Europhys. Lett.* (in press) 2008

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