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Compressive sampling for energy spectrum estimation of turbulent flows

Recent results from compressive sampling (CS) have demonstrated that accurate reconstruction of sparse signals often requires far fewer samples than suggested by the classical Nyquist–Shannon sampling theorem. Typically, signal reconstruction errors are measured in the ℓ^2 norm and the signal is assumed to be sparse, compressible or having a prior distribution. Our spectrum estimation by sparse optimization (SpESO) method uses prior information about isotropic homogeneous turbulent flows with power law energy spectra and applies the methods of CS to 1-D and 2-D turbulence signals to estimate their energy spectra with small logarithmic errors. SpESO is distinct from existing energy spectrum estimation methods which are based on sparse support of the signal in Fourier space. SpESO approximates energy spectra with an order of magnitude fewer samples than needed with Shannon sampling. Our results demonstrate that SpESO performs much better than lumped orthogonal matching pursuit (LOMP), and as well or better than wavelet-based best M-term or $M/2$-term methods, even though these methods require complete sampling of the signal before compression.