EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE LAUSANNE
POLITECNICO FEDERALE DI LOSANNA
SWISS FEDERAL INSTITUTE OF TECHNOLOGY LAUSANNE

Institut de Génie Mécanique

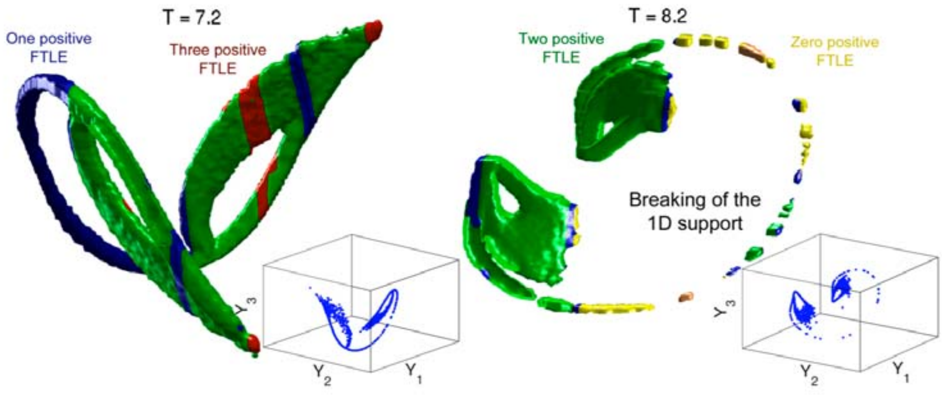
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Seminar given by Dr. Themistoklis Sapsis on March 16, 2012, at 9:30

New York University, USA

Interplay of dynamical instability, stochasticity, and nonlinear energy transfer in fluid and mechanical systems

We present a new perspective for complex systems based on the interplay between energy exchanges (energy transfer rates, energy cascades, and spectra), dynamical features (such as instabilities, bifurcations, and Lyapunov exponents), and statistical characteristics (such as probability density functions, correlation functions, and rare events). All of these notions have been used in the past, usually independently from each other, to describe complexity in various scientific fields. Turbulence is perhaps the most famous example of such complexity although mechanical systems may also present similar features. We establish a rigorous link showing inherent interplay and connections of the above viewpoints, and highlighting the necessity to consider them from a unified perspective. To demonstrate this we focus on the problem of unstable fluid flows. First, we present an efficient uncertainty quantification scheme that allows for the nonlinear evolution of statistics based on a stochastic, order-reduction framework. Using this stochastic approach, which fully respects and accounts for the nonlinear dynamical features of the system, we illustrate how linearly stable and unstable modes operate synergistically with essentially nonlinear, conservative, energy transfer mechanisms to produce an energy cascade which results in collapse of the probability measure in low-dimensional sets. The aforementioned findings are based on rigorous theorems that are demonstrated by specific numerical applications. In the last part of the talk we show how these ideas can be used for the design of mechanical analogues of turbulent energy cascades, in order to perform irreversible nonlinear targeted energy transfer between structural components of mechanical systems. In particular, by attaching light-weighted, essentially nonlinear, attachments to a main structure we are able to passively 'guide' energy to specific modes of motion.



Collapse of the probability measure in lower dimensional sets as a result of energy cascade in transient turbulence.