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Physical Colloquium

„Simplifying the Description of Turbulent Flows: Using the Zero Crossings of a Signal to Characterize Its Dynamics“

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Monday, 01.07.2024, 2.15 p.m.
Room No. W02 1-148

Turbulent flows have been intensively studied for the last century. They remain one of the most important unsolved problems in physics, as we are not capable of predicting the flow field from a given set of boundary conditions in realistic scenarios. This severely limits our ability to model and describe systems as varied as galaxies, weather patterns, wind farms, or even fluid movement in pipes. The complexity of turbulent flows lies in several aspects, including their nonlinear dynamics and the non-locality of the pressure term. They are out-of-equilibrium systems with a very large number of degrees of freedom. Consequently, their characterization is extremely challenging both theoretically and experimentally.

A promising approach to studying turbulent flows involves using the zero crossings of a velocity signal along with different aspects of stochastic processes theory. It is well known that the zero crossings of the longitudinal velocity fluctuations can estimate the Taylor length scale of turbulence, thanks to Rice‘s theorem. Furthermore, recent research by Mora & Obligado (Exp. Fluids, 2020) has found that zero crossings can also be used to compute the integral length scale. As a result, they can be exploited to study several one-point statistics of turbulent flow and even relate them to aspects of the energy cascade. This approach presents several advantages as it enables the characterization of turbulent flow in extremely challenging situations, where the flow is unsteady or proper calibration of the equipment cannot be guaranteed.

Using experimental data from different flows (passive- and active-grid-generated turbulence, planar and axisymmetric turbulent wakes) across a wide range of Reynolds numbers, we demonstrate how different averaged properties of the energy cascade can be described using solely the zero crossings of the longitudinal velocity fluctuations. Furthermore, we show how the small-scale intermittency of the flow can be quantified, at a first order, using these structures. Finally, using Voronoi tessellations, we studied the clustering properties of zero crossings. In particular, we show how their voids are related to the characteristics of the energy cascade.

Host: Prof. Dr. Joachim Peinke