DY 16: Fluid dynamics I

Time: Wednesday 14:45–18:00 Location: ZEU 255

DY 16.1 Wed 14:45 ZEU 255

Measuring the Effect of Dynamic Stall — •Jörge Schneemann, Gerrit Wolken-Möhlmann, and Joachim Peinke — Universität Oldenburg, Institut für Physik, Germany

An airfoil in laminar inflow experiences static lift and drag forces. Under turbulent conditions dynamic effects like dynamic stall take place. We present measurements of dynamic stall in a closed test section of a wind tunnel using the pressure distribution on the wind tunnel walls to calculate lift forces. Dynamic stall was induced by pitching the foil sinusoidally. Pressure sensors placed in the foil were used to study the dynamics of the separation point. Our next task is to install a strain gauge based system for measuring radial forces on the mounting of the foil that will allow to investigate dynamic stall under turbulent conditions.

DY 16.2 Wed 15:00 ZEU 255

3D flow measurement with Digital Holographic Particle Tracking Velocimetry (DHPTV) — •Tim Homeyer and Gerd Gülker — Carl von Ossietzky University Oldenburg - Institute of Physics - Hydrodynamics and Windenergy, Germany

The two-dimensional flow measurement technique PIV (Particle Image Velocimetry) is a standard method to investigate air or fluid flows. After seeding the fluid with small light scattering particles, a laser light sheet is created, and two fast consecutive images of the illuminated field are recorded. These images are correlated in a computer and resulting in a two-dimensional vector field of the flow velocity.

This technique is extended to the third dimension using holography (Holographic PIV). By recording a volume in a hologram and subsequent reconstruction, the whole three-dimensional particle field of the flow is captured.

For small volumes, one can also record the holograms with a digital camera, instead of using film material. This has the advantage that recording and reconstruction is directly performed in the computer and no chemical development and additional digitizing is needed. Due to noise the number of particles has to be reduced. That is why each particle is identified, validated and tracked through the volume (Particle Tracking Velocimetry) instead of performing a 3D correlation (PIV).

The goals of this diploma thesis are to design a DHPTV system to record small three-dimensional flows in a wind tunnel and in Rayleigh-Bénard-Cells and to compare different types of particle validation methods.

DY 16.3 Wed 15:15 ZEU 255

Statistical analysis of non-stationary atmospheric boundary layer turbulence — •Thomas Laubrich and Holger Kantz — Max-Planck-Institut fuer Physik Komplexer Systeme; Noethnitzer Str. 38, 01187 Dresden, Germany

We study the statistics of the horizontal component of atmospheric boundary layer wind speed. Motivated by its non-stationarity, we investigate which parameters remain constant or can be regarded as being piece-wise constant and explain how to estimate them. We will verify the picture of natural atmospheric boundary layer turbulence to be composed of successively occurring close to ideal turbulence with different parameters.

The first focus is put on the fluctuation of wind speed around its mean behaviour. We describe a method estimating the proportionality factor between the standard deviation of the fluctuation and the mean wind speed and analyse its time dependence. The second focus is put on the wind speed increments. We investigate the increment statistics and show that the parameters describing the distribution change with time by using superstatistics and simulated annealing optimisation.

DY 16.4 Wed 15:30 ZEU 255

Stochastic analysis of fractal-generated turbulence — •Robert Stresing[1], J. Christos Vassilicos[2], and Joachim Peinke[1] — [1]Inst. of Physics, University of Oldenburg, Germany — [2]Dep. of Aeronautics & Inst. of Math. Sciences, Imperial College, London, UK

We present a stochastic analysis of turbulence data, which provides access to the joint probability of finding velocity increments at several scales. The underlying stochastic process in form of a Fokker-Planck equation can be reconstructed from given data. Intermittency effects are included. The stochastic process is Markovian for scale separations larger than the Einstein-Markov coherence length, which is closely related to the Taylor microscale.

We extend our analysis to turbulence generated by a fractal square grid. We find that in contrast to other types of turbulence, like free-jet turbulence, the coefficients of the Fokker-Planck equation do not depend on the Reynolds number, and the n-scale statistics are universal over the entire range of Taylor based Reynolds numbers from 150 to 740. Thus we propose to have found a new class of Reynolds-number independent turbulence generated by boundary conditions of a fractal grid.

Ref.: R. Friedrich, J. Peinke, Phys. Rev. Lett 78, 863 (1997); C. Renner, J. Peinke, R. Friedrich, O. Chanal, B. Chabaud, Phys. Rev. Lett 89, 124502 (2002); R. E. Seoud, J. C. Vassilicos, Phys. Fluids 19, 105108 (2007); R. Stresing, J. Peinke, R. E. Seoud, J. C. Vassilicos, in: Progress in Turbulence III, Springer, forthcoming

DY 16.5 Wed 15:45 ZEU 255

Escape from turbulence in shear flows — •Alberto de Lozar and Björn Hof — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Deutschland

The collapse of turbulence, observable in shear flows at low Reynolds numbers, raises the question if turbulence is generically of transient nature or becomes sustained at some critical point. Recent data have lead to conflicting views with the majority of studies supporting the model of turbulence turning into an attracting state. We have performed lifetime measurements of turbulence in pipe flow spanning eight orders of magnitude in time, drastically extending all previous investigations. We show that no critical point exists in this regime and that in contrast to the prevailing view the turbulent state remains transient. The behavior found here identifies turbulence in pipe flow as a type-II super-transient, which had been conjectured as a potential description of turbulence two decades ago. Additionally we investigate the lifetime behaviour for square duct and plane Poiseuille flow in order to establish in how far this transition behaviour and the collapse of turbulence are general features of shear flows.

DY 16.6 Wed 16:00 ZEU 255

Control of Intermittent Turbulence in Pipe Experiments — •Bjoern Hof, Alberto de Lozar, and Devranjan samanta — Max Planck Institut fuer Dynamik und Selbstorganisation, Goettingen, Deutschland

Despite more than a century of research the onset of turbulence in pipe flow is still not well understood. Flows can in principle remain laminar for all Reynolds numbers (Re) but in practice, unless great care is taken, transition already occurs at moderate values of Re. Typically in the transitional regime flows change intermittently between laminar and turbulence. Here we study the dynamics at the interface between the two states of the flow. An instability mechanism is identified which continuously transfers energy from the laminar to the turbulent motion. From the observed dynamical behaviour we can rationalize the intermittent dynamics and why turbulent structures remain localized in this Re regime. Furthermore, having identified the energetically most active region of the flow, we are able to apply a simple control mechanism to intercept the energy transfer. In experiments carried out at relatively low Reynolds numbers this simple control concept is sufficient to destroy the localized turbulent structures. When this procedure is applied continuously turbulence can be fully omitted downstream of the control point.

15 min. break.

DY 16.7 Wed 16:30 ZEU 255

Numerical simulations of localized turbulence in shear flows — •Marc Avila and Bjoern Hof — Max Planck Institute für Dynamik und Selbstorganisation, Bunsenstraße 10, 37073 Göttingen, Germany

Subcritical transition to turbulence in shear flows has been recently interpreted in terms of novel developments in low-dimensional dynamical systems theory. At moderate Reynolods numbers, the flows are characterized by the presence of turbulent patches which are bounded by laminar regions. On the theoretical side, these states have been linked to the presence of a chaotic saddle embedded in the infinite-

dimensional phase space of the Navier-Stokes equations. Experiments and numerical simulations show that at low Reynolds number localized turbulent states are transient, their lifetimes following and exponential distribution in accordance to theoretical predictions. However, conlifcting views are held in the community as to the transient behaviour of turbulence when the Reynolds number is increased. Instead, the focus of this contribution is on the understanding of the physical mechanisms feeding localized turbulent states. Numerical simulations are conducted in order to obtain pressure and vorticity distributions, as well as propagation speeds. Particular attention is paid to the spatial resolution requirements that need to be met in order to faithfully resolve the nonlinear dynamics.

DY 16.8 Wed 16:45 ZEU 255

Basin boundary, edge of chaos and edge state in a two-dimensional model — •Jürgen Vollmer[1,2], Tobias Schneider[2], and Bruno Eckhardt[2] — [1]Dept. Dynamics of Complex Fluids, MPI for Dynamics & Self-Organization, 37073 Göttingen, Germany — [2]FB Physik, Philipps Univ. Marburg, 35032 Marburg, Germany

Basin boundaries are the boundaries between the basins of attraction of coexisting attractors. When one of the attractors breaks up and becomes a transient repelling structure also the basin boundary disappears. Nevertheless, it is possible to distinguish the two types of dynamics in phase space and to define and identify a remnant of the basin boundary, the edge of chaos. We here demonstrate the concept using a two-dimensional (2D) map, and discuss properties of the edge of chaos and its invariant subspaces, the edge states. The discussion is motivated and guided by observations on certain shear flows like pipe flow and plane Couette flow where the laminar profile and a transient turbulent dynamics coexist for certain parameters, and where the notions edge of chaos and edge states proved to be useful concepts to characterize the transition to chaos. The 2D map captures many of the features identified in laboratory experiments and direct numerical simulations of hydrodynamic flows.

DY 16.9 Wed 17:00 ZEU 255

Quantification of mixing in micro-channels using finite time Lyapunov exponents — Aniruddha Sarkar and •Jens Harting — Institute for Computational Physics, University of Stuttgart, Germany.

The staggered herring-bone mixer (SHM) is a chaotic micromixer, which was recently developed by A.Stroock et al.. We obtain mixing here by a process called "chaotic advection", which occurs due to repeated stretching and folding of the fluid interfaces, even at low Reynold's number.

The ability of the fluids to mix well depends on the rate at which chaotic advection occurs in the mixer. In order to calculate the chaotic strength of a micromixer, we analyse finite-time Lyapunov exponents(FTLE). We simulate the fluid flow using the lattice Boltzmann method(LBM), introduce massless and non interacting tracer particles and from their trajectories we calculate the Lyapunov exponents. We calculate the Lyapunov exponents and then use this method to optimize the performance of the SHM. We varried the geometrical structures of the SHM and reproduce the optimal parameters known from the literature. Further we show that the mixing properties can be increased by adding hydrophobic surfaces.

DY 16.10 Wed 17:15 ZEU 255

Determining role of Krein signature for three-dimensional Arnold tongues of oscillatory MHD dynamos — •Oleg Kirillov[1], Uwe Guenther[2], and Frank Stefani[2] — [1]Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, D-01314 Dresden, Germany

Using a homotopic family of boundary eigenvalue problems for the mean-field α^2-dynamo with helical turbulence parameter $\alpha(r) = \alpha_0 + \gamma\Delta\alpha(r)$ and homotopy parameter $\beta \in [0,1]$, we show that the underlying network of diabolical points for Dirichlet (idealized, $\beta = 0$) boundary conditions substantially determines the choreography of eigenvalues and thus the character of the dynamo instability for Robin (physically realistic, $\beta = 1$) boundary conditions. In the $(\alpha_0, \beta, \gamma)-$space the Arnold tongues of oscillatory solutions at $\beta = 1$ end up at the diabolical points for $\beta = 0$. In the vicinity of the diabolical points the space orientation of the 3D tongues, which are cones in first-order approximation, is determined by the Krein signature of the modes involved in the diabolical crossings at the apexes of the cones. The Krein space induced geometry of the resonance zones explains the subtleties in finding α-profiles leading to spectral exceptional points, which are important ingredients in recent theories of polarity reversals of the geomagnetic field.

DY 16.11 Wed 17:30 ZEU 255

Observation of the Interaction of Magnetic Particles in a Rotational Magnetic Field — •Simone Herth, Alexander Weddemann, and Andreas Hütten — Fakultät für Physik, Universität Bielefeld, Germany

The manipulation of magnetic particles on chip gained interest in the field of microfluidic systems, medical physics, such as hyperthermia, or nanobiotechnology in general. Especially, the advantages of magnetic particles include their possibility to be manipulated by an external magnetic field, detected by magnetoresistive sensors, and their easy handling.

If magnetic particles are under the influence of a rotational magnetic field, their interaction strongly depends on the frequency of the rotation. Starting with a low frequency of an applied rotational magnetic field, which arranges the particles in chains, the particles will finally not be influenced by the magnetic field at all at very high frequency. However, numerical simulations show that there is a critical frequency, which leads to a repulsive force between the particles (see abstract titled "Interactions of Magnetic Particles in Non-Magnetic Liquids"). The critical frequency depends on the particle size, the saturation magnetisation as well as the applied field and can be analysed by microscopic observations.

The talk will analyse the videos taken of moving particles in a rotational magnetic field at various frequencies, compare the results with simulations, and discuss some applications.

DY 16.12 Wed 17:45 ZEU 255

Interactions of Magnetic Particles in Non-Magnetic Liquids — •Alexander Weddemann, Simone Herth, and Andreas Hütten — Bielefeld University, Universitätsstraße 25, D-33615 Bielefeld, Germany

Magnetic particles on the micro- or nanoscale, so called magnetic beads, have a growing number of different applications in many different physical, chemical or medical fields, e.g. as contrast agents or drug carriers. One of their most important features is the possibility to manipulate them in e.g. microfluidic devices by an external magnetic field. However, external fields also align the magnetic moment vectors, which leads to high forces between particles on short distances inducing very strong fluid flows. Especially, though strong magnetic forces occur in these systems, they eventually do not exceed the hydrodynamic interactions of the particles anymore. To investigate the different force contributions, the behaviour of particles in a rotational or alternating homogenous magnetic field is analysed. We discuss the dependency of particle motion with respect to field frequency as well as the particle properties, e.g. size or saturation magnetization. Furthermore, the contributions of magnetic and hydrodynamic forces are discussed.

The experimental aspects of such systems are discussed in the presentation 'Observation of the Interaction of Magnetic Particles in a Rotational Magnetic Field'.