DY 26: Focus Session: Percolation and turbulent transition

(Organizers Björn Hof and Marc Avila)

Time: Wednesday 9:30–12:30 Location: BH-N 243

Invited Talk DY 26.1 Wed 9:30 BH-N 243
Elusiveness of experimental evidence for directed percolation critical behavior — •Hugues Chaté — CEA-Saclay, Service de Physique de l'Etat Condensé, CNRS UMR 3680, Gif-sur-Yvette, France

The directed percolation universality class contains all generic continuous phase transitions into an absorbing state. It should in principle be observed in situations where an 'active' state is in an effectively-stochastic local competition with an 'absorbing' state from which no fluctuation allows to escape.

Such situations a priori abound: fires, epidemics, various invasion and front propagation processes, etc. In 1986, Pomeau even made the bold claim that the statistical, large-scale, properties of subcritical transitions to turbulence in shear flows, such as the plane Couette flow, should fall into the directed percolation class.

Hundreds of models have been shown to exhibit the universal critical behavior of directed percolation, which is also well understood at the field-theoretical level. Yet, comprehensive, unambiguous experimental evidence for it remains scarce.

In this talk, I will present this situation in more detail and discuss the reasons why experimental evidence for directed percolation scaling remains so elusive. I will describe the only fully-convincing case found by Takeuchi et al. in 2007. I will conclude with a cautious but optimistic viewpoint for the case of shear flows: almost thirty years after Pomeau's conjecture, we may finally be near obtaining confirmation that his seminal insight was well-founded.

Invited Talk DY 26.2 Wed 10:00 BH-N 243
Spatio-temporal dynamics in pipe flow and boundary layers — •Bruno Eckhardt — Philipps-Universität Marburg

The transition to turbulence comes in two varieties: in one case, the laminar profile becomes linearly unstable, and a subsequent cascade of instabilities results in the spatially and temporally fluctuating turbulent state. A fluid heated from below (Rayleigh-Benard problem) is the paradigmatic example for this situation. In other cases, turbulence sets in even though the laminar profile remains linearly stable. This 'bypass transition' is typically observed in pipe flow, boundary layers and other shear flows. The turbulence is spatially heterogeneous and temporally transient, with the linearly stable laminar state as an absorbing state. Considerable numerical and experimental data support a model for the bypass transition that builds on localized exact coherent structures and their homoclinic and heteroclinic connections, the spatio-temporal dynamics of excitable media, and the statistical mechanics of directed percolation.

DY 26.3 Wed 10:30 BH-N 243
Transition to sustained turbulence in pipe flow: a second order phase transition? — •Vasudevan Mukund and Björn Hof — Institute of Science and Technology Austria, Klosterneuburg, Austria

In a recent study, the critical point for sustained turbulence in a pipe was estimated to be Re ≈ 2040, by balancing the times scales for turbulence growth and decay processes. This work brought into focus the spatio-temporal aspects of the transition and suggested the possibility that the transition is a second order non-equilibrium phase transition. The present contribution aims to experimentally characterize the transition to sustained turbulence in pipe flow in greater detail and explore the analogy to a phase transition. However, the long time scales near the critical point ($\approx 10^7$ advective time units) pose a challenge in realizing this. We circumvent this problem by constructing a set-up with a quasi-periodic pipe, that exploits the memoryless nature of the turbulence spreading and decay processes in the vicinity of the critical point. In conjunction with an accurate control of the Reynolds number, it is then possible to monitor the spatio-temporal dynamics for arbitrarily long times, and obtain quantities such as the equilibrium turbulent fraction. We present evidence to support the idea that the transition to sustained turbulence in pipe flow is a phase transition of second order and provide first estimates of some of the associated critical exponents.

DY 26.4 Wed 10:45 BH-N 243
Critical exponents for the onset of turbulence in Couette flow — Liang Shi and •Björn Hof — IST Austria, Klosterneuburg, Austria

At onset turbulence appears in localized patches surrounded by laminar flow. While individual spots eventually decay, they can also seed new ones in their neighbourhood. As the Reynolds number is increased turbulence becomes sustained once the rate of spot generation outweighs the decay rate of spots. In direct numerical simulations of Couette flow we determine the resulting turbulent fractions and size distributions close to this critical point. The exponents describing the scaling of the turbulent fraction, as well as those for correlation length and correlation times at critical are in excellent agreement with directed percolation.

15 min. break

DY 26.5 Wed 11:15 BH-N 243
About discontinuous laminar-turbulent transitions in planar shear flows — •Yohann Duguet — LIMSI-CNRS, Université Paris-Sud, Orsay, France

The suggestion that transitional shear flows with a stable laminar state could be described as stochastic contact processes was formulated almost three decades ago. Recent progresses in pipe flow experiments and simulations have allowed for firmer claims about the universality class to which it belongs, with an emphasis on the university class of directed percolation. In this flow we would like to discuss two planar flows also featuring competition between laminar and turbulent phases, by analysing the mechanisms for the collapse of turbulence from accurate numerical simulations in large domains. For the case of planar Couette flow, the question seems to remain open even judging from recent observations. The case of a parallel boundary layer flow with uniform suction, however, shows a clear example of brutal discontinuous phase transition. We will discuss the crucial differences between the local mechanisms in these two examples. This is joint work with the Mechanics department of KTH (Stockholm, Sweden).

DY 26.6 Wed 11:30 BH-N 243
Transition to turbulence in Couette-Taylor flow as a directed percolation process ? — •Grégoire Lemoult[1], Shreyas Jalikop[1], Kerstin Avila[2], and Björn Hof[1] — [1]IST Austria (Institute of Science and Technology, Klosterneuburg, Austria) — [2]Institute for Multiscale Simulation at the Friedrich-Alexander Universität Erlangen-Nürnberg

In the counter-rotating regime of Couette-Taylor (CT) flow, turbulence appears abruptly through spatio-temporal intermittency (STI). STI is observed during the sub-critical transition to turbulence in many shear flows, most notably pipe flow and Couette flows. K. Avila *et al.* (Science 333, 2011) recently characterized the onset of sustained turbulence in pipe flow. Their work suggested that the transition could be a second order non-equilibrium phase transition. The present contribution aims to experimentally characterize the transition to sustained turbulence in CT flow and explore the analogy to a phase transition.

Our CT setup has an aspect ratio and an azimuthal length of more than 600 gap-widths. These large dimensions minimise the finite-size effects, and render the setup suitable to experimentally investigate the spatio-temporal dynamics. We present evidence to support the idea that the transition is a phase transition of second order and provide first estimates of some of the associated critical exponents: laminar gap size distributions and turbulent fraction.

DY 26.7 Wed 11:45 BH-N 243
Emerging spatiotemporal dynamics in fluid flow — •Marc Avila[1], Paul Ritter[1], and Fernando Mellibovsky[2] — [1]FAU Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]UPC, 08860 Castelldefels, Spain

As of today, no theoretical framework fully describes the emergence of turbulent dynamics in shear flows. A dynamical-systems approach suggests that invariant solutions to the Navier-Stokes equations, like traveling waves and relative periodic orbits in pipe flow, act as building blocks of the disordered dynamics. While recent studies have shown how transient chaos arises from such solutions, the ensuing dynamics lacks the strong fluctuations in size, shape and speed of turbulent spots observed in experiments. In this talk I will show that the interaction of chaotic spots with distinct dynamical and kinematic properties gives rise to enhanced spatiotemporal fluctuations, providing a bridge from chaos toward turbulence. The link between the phase-space interpretation of the dynamics and percolation-like models will be discussed.

DY 26.8 Wed 12:00 BH-N 243

Localized periodic orbits in plane channel flow — •Stefan Zammert and Bruno Eckhardt — Philipps-Universität Marburg

Exact solutions of the Navier-Stokes equation are assumed to form a skeleton for turbulent dynamics. Therefore, within the last two decades the study of exact solutions has attracted lots of attention. Nevertheless, until now there is a lack of localized solutions for plane shear flows that could help to understand the formation of turbulent spots. Using direct numerical simulation we were able to identify streamwise and doubly-localized relative periodic orbits that are exact solutions of the Navier-Stokes equations (Zammert& Eckhardt: J. Fluid Mech. 761, 348-359 (2014)) for plane channel flow. We will discuss the dependence of these structures on the Reynolds number and we will show that they are created in bifurcations of spatially extended travelling wave solutions.

DY 26.9 Wed 12:15 BH-N 243

Zeitaufgelöste High Speed PIV Untersuchung von Ablösepunkt und Transition in der Grenzschicht eines Tragflügels — •Tom Wester, Dominik Traphan, Gerd Gülker und Joachim Peinke — ForWind, Institut für Physik, Universität Oldenburg, 26111 Oldenburg, Deutschland

Zur Optimierung von Windkraftanlagen ist der Umschlag von laminarer zu turbulenter Grenzschicht auf den Rotorblättern ein wichtiger Design-Parameter. Dieses Strömungsphänomen wird durch die Turbulenzintensität der Umgebung, sowie durch den Anstellwinkel des Profils stark beeinflusst. In der atmosphärischen Grenzschicht ist eine Windkraftanlage ständig wechselnden Anströmungsbedingungen ausgesetzt. Dies macht die Dynamik des laminar-turbulenten Umschlages, sowie des Strömungsabrisspunktes besonders interessant. Damit diese Phänomene zeitlich und räumlich gut aufgelöst werden können, wird in dieser Studie High-Speed Stereo Particle Image Velocimetry (HS-PIV) verwendet. Hierdurch wird weiter die Analyse der bisher noch nicht ausreichend untersuchten Dynamik der Transition und des Strömungsabrisses an Rotorblättern möglich. Dies soll unter verschiedenen Anströmbedingungen erforscht werden, wobei erste Ergebnisse eine deutliche Abhängigkeit von diesen zeigen und zur Lastminimierung an Windkraftanlagen, sowie zu Validierung von CFD-Simulationen beitragen können. Auch können die Ergebnisse zur Entwicklung neuer stochastischer Modelle für den laminar-turbulenten Umschlag beitragen.