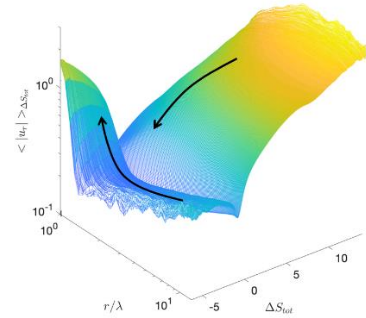

Workshop on different states of turbulence and transitions from one state to the other: small and large-scale aspects and their interrelations.

Grenoble (LEGI, amphi batiment K) 13 and 14 February 2019

Based on previous workshops in the frame of LANEF Chair of excellence, we plan a meeting to advanced analysis of turbulence measurements of Grenoble and Oldenburg based on some new findings (see topics below). The workshop is also thought as a preparation for a conference on this topic to be held in summer 2019 or later (tbd), and will be organized so that there is time to work out some new ideas.

This workshop will focus on two specific aspects:

(1) 13.2. 2019 -- Aspects of small scale turbulence and cascades will be discussed in terms of stochastic thermodynamics in connection to large deviation theory, entropy fluctuations and fluctuation theorems, and non-equilibrium statistical mechanics.

(2) 14.2.2019 -- The large scale and average behaviors of evolving turbulent flows such as wakes of fractal and classical discs and wind turbines, as well as the development of turbulence as a consequence of multiscale excitations (such as by active or multiscale/fractal grids) will be discussed in the context of cascade and turbulence dissipation phenomena. The universality and scalings of such phenomena in both equilibrium and non-equilibrium cascade situations will be a particular focus.

For each topic there will be half a day (morning) of presentations and half a day (afternoon) of discussions and conceptional work where presentation of preliminary results should be discussed.

The presentations in the morning are open for every interested person, the workshops in the afternoon are open only for preregistered/invited participants (for invitation please contact joachim.peinke@uni-oldenburg.de and alain.girard@cea.fr)

Organizing Team: Joachim Peinke, Martin Obligado, Mathieu Gibert, Alain Girard

Workshop
Different states of turbulence and transitions from one state to the other: small and large-scale aspects and their interrelations

February 13th – 14th, 2019 | Grenoble, France

time	Wednesday (13th of February) Turbulence and rare events
09:00	Welcome –
	Session 1
09:15 – 10:00 10:00 – 10:30	**Freddy BOUCHET:** Rare events in turbulent flows **Andre FUCHS:** Fine structure of turbulence determined by entropy variation
10:30 – 11:00	**Coffee and discussion**
	Session 2
11:00 – 11:30 11:30 – 12:00 12:00 – 12:30	**Philippe ROCHE**: Detection of different states of turbulence at very high Ra **Ingrid NEUNABER:** Evolution of turbulence downstream wind turbines **Wouter BOS:** Power fluctuations in turbulence

time	Thursday (14th of February) turbulence and transitions
	Session 3
09:00 – 09:45 09:45 – 10:15	**Christos VASSILICOS:** Unsteady turbulence cascades and dissipation **Antoine NAERT:** Measurement of temperature in turbulence
10:15 – 10:45	**Coffee and discussion**
	Session 4
10:45 – 11:15 11:15 – 11:45 11:45– 12:15	**Martin OBLIGADO**: Turbulent cascades in active grid generated turbulence **Lars NEUHAUS:** Transition to highest Reynolds number turbulence by active grid and wind tunnel control **Marcello MELDI:** Sensitivity of anomalous very fast decay regimes to multiscale production mechanisms in isotropic turbulence

Abstracts:

Freddy BOUCHET (ENS Lyon): Rare events in turbulent flows .

I will review three applications of rare event algorithms and large deviation theory for important rare events in turbulent flows. Rare event of a first class matter because they have a huge impact. The first example will be extreme drags on objects embedded in a turbulent flow. The second example will be extreme heat waves in climate dynamics. Rare event of a second class matter because they drive the system from one attractor to a completely different one. The example we will discuss are rare transitions between jets in atmosphere dynamics.

Andre FUCHS (U Oldenburg): :**On the fine structure of turbulence determined by entropy variation**

Using a non-equilibrium thermodynamical approach together with a stochastic description of the turbulent cascade process allows a new access to the dynamic fluctuations induced by the highly nonlinear, nonlocal and chaotic turbulent small scale structures, which are typical features observed in developed turbulence. Our investigation show that entropy-consuming trajectories are correlated to extreme events in the increment statistics on the smallest scales. These extreme small scale structures (small-scale intermittency) are one of the challenging properties of turbulence. This new approach to turbulence provides a significant gain in information, especially about these small scale intermittent structures. Our results are based on the analysis of constant temperature hot-wire anemometry measurements of velocity of fractal grid turbulence in a wind tunnel. Moreover, the presented results indicate a link between the statistical description of turbulence and the characterization via local turbulent flow structures.

Philippe ROCHE (NEEL): Detection of different states of turbulence at very high Ra

Over the last 2 decades, the “ultimate state” has become the most debated topic in the field of turbulent convection. More than a dozen of Rayleigh-Bénard experiments conducted at very large Rayleigh numbers produce apparently contradictory results, with diverging heat transfer efficiencies. The nature of the transition is vividly debated in the community, as well as the condition for its occurrence. We will present a meta-analysis of all experimental data and present evidence that all experiments could have entered the ultimate regime, but some in a damped “silent mode”, calling for new exploration tools.

Ingrid NEUNABER: (U Oldenburg) Evolution of turbulence downstream wind turbines

Within the framework of turbulence evolution, the wakes generated by wind energy converters are investigated. A model

wind turbine and a so-called actuator disc are exposed to laminar and different turbulent inflows generated by a grid and the wake of upstream turbine. The wakes are scanned using hot-wire anemometry at several radial and downstream positions. The data is analyzed using one- and two-point statistics, and the focus is on the downstream evolution of the energy spectral density and the intermittency. To take into account the development of the energy dissipation downstream the turbine, the validity of the equilibrium dissipation law is examined.
The results show the existence of five downstream regions within the turbulence evolution downstream the turbine. Additionally, radial regions such as a ring of high intermittency surrounding the wake and a region of homogeneous isotropic in the center of the far wake can be identified. The existence of these regions can be verified for all inflows. It is thus concluded that a turbine creates an own kind of turbulence that tends towards an equilibrium state far downstream.

Wouter BOS (ECLyon): Power fluctuations in turbulence
In collaboration with Rémi Zamansky (IMFT Toulouse)

To generate or maintain a turbulent flow, one needs to introduce kinetic energy. This energy injection necessarily fluctuates and these power fluctuations act on all turbulent excited lengthscales. If the power is injected using forces proportional to the velocity, such as common in shear flows, or with a force acting at the largest scales only, the spectrum of these fluctuations is shown to have a universal inertial range.

Christos VASSILICOS (Imperial College): Unsteady turbulence cascades and dissipation

A dissipation scaling which is different from the Kolmogorov equilibrium cascade scaling is present in many turbulent flows including turbulent jets, wakes, grid turbulence, forced and decaying periodic turbulence, turbulent boundary layers and perhaps other turbulent flow too. It reflects a non-equilibrium unsteady cascade and has first order consequences on mean flow profiles, entrainment and the Turbulent/Non-Turbulent Interface (TNTI) velocity. There are indications that its presence is linked to large-scale coherent structures and that the turbulence transits to a different dissipation scaling and a different non-equilibrium cascade when the effect of these structures dies out. The turbulence cascade is in fact extremely intermittent in both space and time involving various types of correlations, in particular between fluctuating pressure gradients and fluctuating velocities.

Marc LAGOIN, Anne MOUNIER, Antoine NAERT, (ENS Lyon): Measurement of temperature in turbulence

Preliminary measurements will be presented, of a protocol allowing to measure a global quantity we call effective temperature of turbulence. Preliminary results will be shown of the Reynolds number dependance of this quantity.

Martin OBLIGADO (LEGI): Energy cascades in active-grid-generated turbulent flows

The energy cascade and diverse turbulence properties of active-grid-generated turbulence are studied in a wind tunnel via hot-wire anemometry. Two active grid protocols are considered: the first one is referred as the triple-random mode, where motors are driven with random rotation rates and directions, which are changed randomly in time. This protocol is widely used in the community as it is known to generate high turbulence levels with good homogeneity and isotropy. The other protocol is a static mode, where all blades are completely open (therefore with the minimum possible blockage).

Centreline streamwise profiles were measured for both protocols and for different freestream velocities. It is found that the turbulent flow generated with the triple-random protocol evolves in the streamwise direction consistently with an energy dissipation scaling of the form $\varepsilon = C_\varepsilon \frac{u'^3}{L}$, with C_ε a constant, L the longitudinal integral length-scale and u' the rms of the longitudinal velocity fluctuations.

On the other hand, the open-static grid produces non-equilibrium turbulence, and therefore $C_\varepsilon \sim \frac{Re_G}{Re_L}$. Re_G is a global Reynolds number based on the inlet conditions of the flow and Re_L is a local one, that depends on the downstream position. Nevertheless, the open-static grid shows some differences with the non-equilibrium turbulence created by other static grids, as the streamwise location of the peak of turbulence intensity is a function of the freestream velocity.

It is also found that a simple theoretical model can predict the value of C_ε from the number density of zero-crossings of the longitudinal velocity fluctuations. This theory is valid for both active grid operating protocols (and therefore two different energy cascades) and has potential applications to the development of turbulent pair dispersion models.

Lars NEUHAUS, Michael HÖLLING, and Joachim PEINKE (U Oldenburg): Transition to highest Reynolds number turbulence by active grid and wind tunnel control

Active grids are commonly used to create highly turbulent flows with high Taylor-scale Reynolds numbers Re_λ. Active grids till now were able to generate flows with Re_λ up to 2000 in air and up to 8000 in pressurized SF_6.
For the big 3x3m² active grid in the large wind tunnel Oldenburg a new excitation method based on a Langevin process was developed. The 30m long wind tunnel allows to study the downstream development of the so generated turbulence and at about 15 m downstream from the grid the evolving turbulence seem to make a rapid transition to a fully developed

turbulent state. Additional excitations of the low frequencies of the flow were achieved by controlling the wind tunnel fans and thus varying the wind speed continuously. For such excitations one of the highest ever generated Re_λ (>10000) turbulence in a wind tunnel by an active grid could be obtained.

Marcello MELDI, P. SAGAUT (ENSMA POITIERS) Sensitivity of anomalous very fast decay regimes to multiscale production mechanisms in isotropic turbulence

In this talk recent findings of the research group about the emergence of anomalous fast decay regimes in homogeneous isotropic turbulence (HIT) decay are summarized. The analyses, performed via both theoretical analysis and Eddy-Damped Quasi Normal Markovian (EDQNM) calculations, allowed the observation of the link between non-standard shapes of the energy spectrum and the emergence of anomalous decay regimes. A detailed analysis of the kinetic energy spectrum E(k) and the non-linear energy transfer T(k) shows that very fast decay regimes are associated with the relaxation of initial energy spectra which exhibit a bump at energetic scales. This feature induces an increase in the energy cascade rate, toward solutions with a smooth classical shape. Present results are in agreement with observations reported in wind tunnel experiments dealing with turbulence decay in the wake of grids and bluff bodies, including scaling laws for the dissipation parameter C_ε. They also indicate that the ratio between the initial eddy turnover time and the bulk flow time determines of how fast anomalous regimes relax toward classical turbulence free-decay."

The talk will be based on a summary of the following three research works I have published on the topic:
1)M. Meldi and P. Sagaut. Investigation of anomalous very fast decay regimes in homogeneous isotropic turbulence. Journal of Turbulence, 19(5) : 390 - 413, 2018.
2)M. Meldi. The signature of production effects on isotropic turbulence decay. Physics of Fluids, 28 : 035105, 2016.
3)M. Meldi, H. Lejemble and P. Sagaut. On the emergence of non-classical decay regimes in multi- scale/fractal generated isotropic turbulence. Journal of Fluid Mechanics, 756 : 816 - 843, 2014.