DY 4: Fluid Physics and Turbulence

Time: Monday 9:30–11:00 Location: BH-N 128

Invited Talk DY 4.1 Mon 9:30 BH-N 128

Towards the ultimate regime in Rayleigh-Benard turbulence — •Olga Shishkina — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Rayleigh-Benard convection – a fluid flow in a container heated from below and cooled from above – is one of the paradigmatic systems in fluid dynamics. Here the key response of the system is the heat transport (Nusselt number Nu) and the key question is: how does Nu depend on the thermal driving strength (Rayleigh number Ra), in particular for extremely large Ra – the case which is relevant in many astrophysical and geophysical systems? We will start with a brief digression into the history of the theory of heat transport scaling relations for large Ra, and in particular for the so-called ultimate regime, where the scaling laws do not change anymore with the further growing Ra. We will discuss the assumptions and outcomes of the various scaling models as well as the factors that influence the transition to the ultimate regime, including the container shape, wall roughness, specific thermal boundary conditions, and possible non-Oberbeck–Boussinesq effects, as well as the multiple-state nature of turbulent thermal convection.

DY 4.2 Mon 10:00 BH-N 128

Statistical modeling of Burgers turbulence with a superposition of characteristic functionals — •Gabriel B Apolinário and Michael Wilczek — Theoretical Physics I, University of Bayreuth, Universitätsstr. 30, 95447 Bayreuth, Germany

We study an ensemble of random fields, each with statistics described by a general characteristic functional. The typical length scale of these fields is a random variable and is used to model intermittency. This ensemble decomposition approach [Wilczek, *New J. Phys.* **18**, 125009 (2016)] allows for an analytically tractable approximation to turbulent statistics, and is applied to the Burgers equation. By choosing smooth correlation functions and an appropriate distribution for the typical length scale, we build a description of Burgers turbulence at an infinite Reynolds number, in which the velocity statistics are Gaussian, but increment and gradient statistics are bifractal. Skewness, a hallmark of turbulent fields, is obtained by truncating a Taylor-expanded cumulant generating functional, and this is shown to be a useful approximation.

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DY 4.3 Mon 10:15 BH-N 128

Ensemble modeling of large-scale intermittency in turbulence — •Lukas Bentkamp and Michael Wilczek — Theoretical Physics I, University of Bayreuth, Germany

Turbulent flows at high Reynolds number are often assumed to have universal small-scale statistics, independent of the precise structure of the large scales. However, many experimental and numerical studies show a large scatter of statistical quantities, in particular with respect to higher-order moments. One reason for this may be large-scale intermittency, i.e. very slow variations of the large scales whose effect is still detectable at the small scales. At the example of homogeneous, isotropic turbulence simulations with sinusoidally varying energy injection rate, we investigate how ensembles of statistically stationary flows can be used to model the impact of large-scale intermittency. In order to build an accurate ensemble model, we find that not only the time series of the mean energy dissipation rate but also statistical fluctuations around it have to be incorporated.

DY 4.4 Mon 10:30 BH-N 128

Low-dimensional description of turbulent superstructures in three-dimensional Kolmogorov flow — •Fabián Álvarez-Garrido and Michael Wilczek — Theoretische Physik I, Universität Bayreuth, Bayreuth, Germany

Certain flows display the coexistence of small-scale turbulence and large-scale turbulent superstructures. Despite the ubiquity of these structures, their interplay with the smaller scales is not yet fully understood. We investigate the three-dimensional Kolmogorov flow as a model flow displaying turbulent superstructures, namely, it features large-scale quasi-two-dimensional vortex pairs. Moreover, we observe non-periodic transitions between states with one and two pairs of these large-scale vortices. We identify these different large-scale states as remnants of two solutions that emerge when a laminar solution looses stability at low Reynolds number where no turbulent fluctuations are present. This allows us to characterize the dynamics of the large scales by keeping track of two complex amplitudes. Through conducting direct numerical simulations, we gathered statistics on these two complex amplitudes and constructed a set of stochastic amplitude equations. The statistical properties of this low-dimensional system can reproduce, up to a fair agreement, the ones observed in the fully three-dimensional Kolmogorov flow. Based on these results, we discuss how the transfer of energy from the large to the smaller scales can stabilize the large-scale vortices, and how the fast-evolving fluctuations can enable the switching between large-scale states, mimicking the mechanism behind noise-induced transitions.

DY 4.5 Mon 10:45 BH-N 128

Dual energy cascade in ocean macroscopic turbulence: Kolmogorov self-similarity in surface drifter observations and Richardson-Obhukov constant — •Julia Dräger-Dietel and Alexa Griesel — Institut für Meereskunde, Universität Hamburg, Hamburg, Germany

We combine two point velocity and position data from surface drifter observations in the Benguela upwelling region off the coast of Namibia. The compensated third order longitudinal velocity structure function <u^3(s)>/s shows a positive plateau for inertial separations s roughly between 9 km and 120 km revealing an inverse energy cascade with energy transfer rate ϵ=1.2 10^-7 m^3/s^2. For scales roughly below 800 m a negative plateau for <u^3(s)>/s indicates to a direct energy cascade with energy-transfer rate 30 times smaller. For both regimes the second order longitudinal velocity structure function <u^2(s)> scales as s^(2/3), as theoretically predicted. Deviations from Gaussianity of the corresponding probability distributions are stronger for the direct cascade in accordeance with theoretical expectation, for instance the kurtosis is 3 times larger. The combination of the energy transfer rate ϵ with Richardson dispersion <s^2(t)>=g ϵ t^3, where <s^2(t)> is the mean squared pair separation at time t, reveals a Richardson-Obhukov constant of g=0.11 for the inverse cascade regime [1].

[1] Draeger-Dietel et al. https://arxiv.org/abs/2311.13560