北京大学力学与工程科学学院
School of Mechanics and Engineering Science

湍流与复杂系统国家重点实验室
State Key Laboratory for Turbulence & Complex Systems

Entropy and fluctuation relation in isotropic turbulence.

报告人: 姚汉逊
中国科学技术大学，近代力学系

2026 年 06 月 05 日 周五 15：00—16：30

地　点：新奥工学大楼 3F - 3048 会议室

主持人：谢金翰

摘要： Turbulence is inherently a multi-scale phenomenon in which nonlinear cascades mediate the redistribution of energy across scales and govern key flow characteristics, including dissipation, scalar mixing, and dispersion dynamics. Turbulent cascades have been rigorously analyzed within the framework of fundamental fluid mechanics, yet their underlying mechanisms and causal origin are not yet fully understood. There has been growing interest in applying concepts from nonequilibrium thermodynamics to classical turbulence. A central motivation is to investigate whether the attractor of turbulent flows can be characterized by a variational or maximal principle analogous to the second law in equilibrium thermodynamics, and whether the cascade operates so as to maximize or minimize the entropy-production rate.

In this work, we define the entropy generation rate in 3D homogenous isotropic turbulence using local properties from the Kolmogorov-Hill equation, featuring the energy cascade rate as well as the `temperature of turbulence' at a prescribed inertial-range length-scale . The fluctuation relation (FR) from non-equilibrium thermodynamics that predicts exponential behavior of positive to negative entropy production rate PDFs has been tested using instantaneous flow fields from isotropic DNS turbulence data. Finally, we attempted to extend the framework and define entropy generation rate in 2D turbulence, which is fundamentally different from 3D turbulence because the inverse cascade is dominant, and the second conserved quantity, enstrophy, plays a central role in determining temperature of 2D turbulence.

报告人简介： Dr. Hanxun Yao is an Assistant Professor in the Department of Modern Mechanics at USTC (Heifei, China). He received his Bachelor, MPhil and PhD from the Ocean University of China, University of Sydney and Imperial College London in Physics, Computational Fluid Dynamics and Turbulence. From 2022 to 2025, he worked as a Postdoctoral Fellow at Johns Hopkins University, where he focused on turbulence theory and the development of the Johns Hopkins Turbulence Databases (JHTDB). His research group works on turbulence theory (energy cascade, multiscale dynamics, intermittency, nonequilibrium thermodynamics) and turbulence modelling from fundamental (homogenous isotropic turbulence, transitional boundary layer, channel flow) to environmental flows (2D turbulence, Rayleigh-Bénard convection, atmospheric boundary layers, magnetohydrodynamics).

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