TT 77: Focus Session: Quantum Turbulence and Imaging of Quantum Flow of Superfluids

Quantum turbulence - turbulent motion of quantum fluids displaying superfluidity, systems such as superfluid helium and atomic Bose-Einstein condensates, which are characterized by quantized vorticity and, at finite temperatures, two-fluid behavior - represents a lively research field linking fluid mechanics, atomic physics, condensed matter, and low-temperature physics. This session covers the central aspects of quantum flows and progress in this field over recent years.

Organization: Ladislav Skrbek, Charles University, Prague; Richard Haley, Lancaster University

Time: Thursday 9:30–12:15 Location: H 0104

Invited Talk TT 77.1 Thu 9:30 H 0104
Quantum Turbulence: New Aspects of an Old Problem — •Carlo F. Barenghi — Newcastle University

Turbulence is everywhere: inside us (aorta flow), in devices which we build (jet engines) and around us (the atmosphere). From a physicist's point of view, turbulence is an old problem; the governing Navier-Stokes equation has been known since the XIX century but predicting solutions is difficult due to the nonlinearity and the huge number of degrees of freedom simultaneously excited. Recent studies have revealed new aspects of the old turbulence problem in superfluid helium and in atomic Bose-Einstein condensates, systems close to absolute zero where quantum mechanics rules the behaviour of macroscopic amounts of matter. In some of the observed regimes, this 'quantum turbulence' is utterly simple (vortex line defects moving in a perfect background) yet it displays the same properties which we observe in ordinary turbulence such as the same distribution of kinetic energy over the length scales. In other regimes quantum turbulence shows different properties, involves unusual forms of energy dissipation or displays turbulent two-fluid behaviour of great complexity. This talk will introduce the problem and its new experimental and theoretical challenges.

[1] C.F. Barenghi, L. Skrbek, and K.R. Sreenivasan, PNAS **111** (Suppl. 1), 4647 (2014).
[2] M.C. Tsatsos, P.E.S. Tavares, A. Cidrim, A.R. Fritsch, M.A. Caracanhas, F.E.A. dos Santos, C.F. Barenghi, and V.S. Bagnato, Phys. Reports **622** 1 (2016).

Invited Talk TT 77.2 Thu 10:00 H 0104
Numerical Simulation of Quantum Turbulence — •Makoto Tsubota — Department of Physics, Osaka City University, Osaka, Japan

Quantum turbulence (QT) is highly nonlinear and nonequilibrium phenomena. Thus numerical simulation is indispensable for studying QT. In this talk, we discuss some important topics of QT in atomic Bose-Einstein condensates (BECs) and superfluid helium. QT in atomic BECs includes several kinds of turbulence like vortex turbulence, wave turbulence, spin turbulence and two-component turbulence. We show these kinds of turbulence, and then focus on the recent confirmation of the cascade flux of QT in BECs trapped by a box potential. Next we discuss the coupled dynamics of the two-fluid model in superfluid helium. Superfluid is described by the vortex filament model and normal-fluid obeys the Navier-Stokes equation, and they are coupled through the mutual friction. Superfluid turbulence makes the normal fluid change its flow profile significantly, which is compared with the recent visualization experiments in thermal counterflow.

The author thanks K. Fujimoto, C. Eigen, J. Zhang, R. Lopes, N. Navon, R. Smith, Z. Hadzibabic, S. Yui and H. Kobayashi for collaboration.

Invited Talk TT 77.3 Thu 10:30 H 0104
Visualising Pure Quantum Turbulence in Fermionic Superfluid — •Viktor Tsepelin — Lancaster University, Lancaster, UK

In this talk, we present experimental and numerical studies of pure quantum turbulence in superfluid ^{3}He-B. While the flow of bulk superfluid must be irrotational, it can mimic classical turbulence by supporting singly quantised vortices. Due to the absence of friction at the lowest temperatures, quantum turbulence is significantly simpler to model than classical turbulence. We demonstrate that, despite stringent requirements to reach one ten-thousandth of a degree from absolute zero, superfluid ^{3}He contains everything required for the generation and study of quantum turbulence. For instance, we do not need to add small tracer particles to visualise turbulence, since the existing ambient thermal excitations, ballistic quasiparticles, can play that role. We explain how to use these ballistic quasiparticles to image vortex tangles produced by a mechanical agitation of the superfluid at velocities above critical. Next we discuss, numerical simulations of a realistic 3D vortex tangle and propagation of quasiparticles through it. This simulation validates the experimental visualization of turbulence and highlights interesting properties of pure quantum turbulence.

The author thanks S. Ahlstrom, A. Baggaley, C.F. Barenghi, D.I. Bradley, S.N. Fisher, E.A. Guise, R. Haley, M. Jackson, G.R. Pickett, Y. Sergeev, N.G. Suramlishvili and A. Woods for collaboration.

15 min. break.

Invited Talk TT 77.4 Thu 11:15 H 0104
Experimental Exploration of Intense Quantum Turbulence with He-II — •Philippe-E. Roche — CNRS, Grenoble, France

The exotic properties of quantum fluids open numerous opportunities to test our understanding of classical turbulence, for example on the role of dissipation and vorticity. However, each type of quantum fluids pose specific experimental challenges when it comes to generate and probe its turbulence. One quantum fluid, superfluid 4He (He-II) has favourable properties that allows to generated very intense quantum turbulence in classical wind-tunnels and stirring cells. In such conditions, a one-to-one direct comparison between classical and quantum turbulences becomes possible. We will present the recent progresses (and stumbling blocks) along this route.

Support from ANR SHREK/ECOUTURB and EC Euhit project is acknowledged

Invited Talk TT 77.5 Thu 11:45 H 0104
Visualization of Superfluid Helium Flows — •Marco La Mantia — Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

The investigation of flows of superfluid helium (He II) constitutes an active and challenging research field. Flow visualization techniques, which allow following the motion of relatively small particles suspended in the fluid, have been specifically giving in recent years significant contributions to our understanding of the underlying physics. It has been shown, for example, that the derived flow-induced properties, such as the velocity statistical distribution, depend on the length scale probed by the particles, for both thermally and mechanically driven flows of He II. Quantum features appear indeed at small enough length scales, smaller than the quantum length scale of the flow, the average distance between quantized vortices, while, at larger scales, a classical (viscous-like) picture emerges, especially in the case of mechanically driven flows. The visualization results obtained to date firmly support the view that the investigation of particle dynamics in quantum flows is not only interesting in its own right but it may also lead to the deeper understanding of fluid turbulence in general.

The author thanks L. Skrbek, M. Rotter, D. Duda, E. Varga, P. Švančara and P. Hrubcová for fruitful discussions and valuable help; the support of the Czech Science Foundation under grant GAČR 16-00580S is acknowledged.