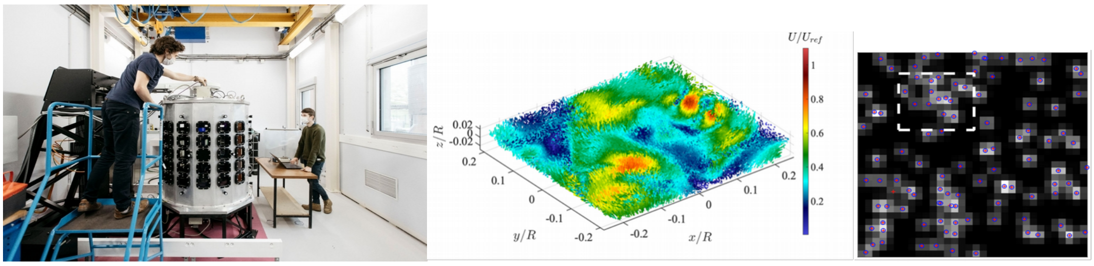
Two years Post-Doc position

Optical metrology in turbulent flows

within the ANR project
Breaking the Kolmogorov barrier in turbulence (BANG)



Subject:

Turbulent flows are ubiquitous in nature and have an impact on many areas of physics, engineering, astrophysics, geophysics and aeronautics. Turbulent flow features vortices and coherent structures of different sizes. The typical size and organization of these structures can be described by a power-law energy spectrum, characteristic of scale-to-scale energy transfer, whereby all energy injected on a large scale is transferred and dissipated on a small scale. The typical scale of energy dissipation is known as the Kolmogorov η scale. Recent theoretical and experimental advances, however, suggest that interesting phenomena occur below η [1] and may have an impact on the validity of the Navier-Stokes (NSE) equations as a model for fluid dynamics. Indeed, below η, energy flows can still occur and create non-viscous dissipation that could constitute true dissipative singularities whose existence could be at the origin of the well-known dissipative anomaly in turbulent flows. The existence of NSE dissipative singularities may have profound implications for the validity of NSE as a fluid model, since differentiability is lost at this stage. Furthermore, according to [2,3] and confirmed by numerical simulations [4], thermal noise from molecular fluid agitation could compete with macroscopic motions at scales smaller than η. More generally, we can assume that the entire structure of small-scale turbulence is affected by thermal fluctuations, which may impact or hinder the development of quasi-singularities.

As part of the BANG project, funded by the French National Research Agency, we are exploring the validity of the Navier-Stokes equation as a fluid model by studying phenomena occurring below the Kolmogorov scale, using multi-scale tools and advanced visualization techniques, namely 4D particle tracking velocimetry (4D-PTV), in a large-scale turbulence experiment called Giant Von Karman (GVK) built at the CEA. The size of this experiment makes it ideally suited to exploring small scales, the

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Kolmogorov scale being of the order of 1 mm. To access small scales, we plan to carry out several 4D-PTV measurement campaigns at GVK, using high particle densities. These experiments will be carried out using LMFL metrological equipment.
To access small spatial scales, high spatial/temporal resolution of our measurement system is needed. There are two paths to a higher resolution in PIV/PTV : higher seeding densities or higher optical zoom with both their associated challenge. Both research paths are being pursed in the BANG project. Two PhD projects are working on a new 4D-PTV software capable of tackling very high image densities as well as large image particle sizes.

The aim of this PostDoc project is to investigate the second idea by first conceiving a specific experimental setup using cameras with very high magnification at LMFL. This new setup should be ideal to explore quasi-singularities at very high Reynolds numbers or thermal agitation. Secondly, once the validity of this setup has been tested, a high-magnification campaign in GVK will be planned in CEA and carried out. Finally, the PostDoc, through data analysis, will be able to investigate the thermal noise and quasi-singularities by looking at the three velocity components at different resolutions. For this, he will be able to use the multi-scale Eulerian and Lagrangian tools developed as part of the ANR EXPLOIT project, which are based on local energy transfers or Lagrangian pair dispersion [1,5,6].

Building on the results obtained at CEA, the post-doc will investigate two main questions. What is the influence of scale on quasi-singularities? What is the effect of Reynolds number on quasi-singularities? How can the thermal noise be characterized? The post-doc will be able to draw on results obtained as part of the EXPLOIT project. Statistics and dynamics will be explored, from Eulerian and Lagrangian points of view.

Once we have completed our analysis, we should have unprecedented knowledge of singularities, their universality and their dynamics. This will help us provide clues to unsolved questions in turbulence, such as the links between quasi-singularities and dissipation, or intermittency.

[1] Dubrulle B. Beyond Kolmogorov, J. Fluid Mech. Perspectives (2019).
[2] R. Betchov On the fine structure of turbulent flows, JFM 3 205-216 (1957); https://doi.org/10.1017/S0022112057000579
[3] R. Betchov Measure of the Intricacy of Turbulence The Physics of Fluids 7, 1160 (1964); https://doi.org/10.1063/1.1711356
[4] Eyink et al Dissipation-Range Fluid Turbulence and Thermal Noise (2021). https://arxiv.org/abs/2107.13954
[5] Cheminet al., Eulerian versus Lagrangian Irreversibility in an Experimental Turbulent Swirling Flow, Physical Review Letter, (2022)
[6] Debue et al., Three-dimensionnal analysis of precursors to non-viscous dissipation in an experimental turbulent flow, Journal of Fuild Mechanics; (2021)

Laboratory: (http://lmfl.cnrs.fr/)
Laboratoire de Mécanique des Fluides de Lille – Kampé de Fériet (LMFL) is a joint laboratory between: ONERA, CNRS, Centrale Lille, University of Lille, Ecole Nationale Supérieure d'Arts et Métiers (ENSAM), where 35 faculties and engineers work in the

fields of turbulence, aerodynamics and flight physics. The team hosting the Post-Doc is involved in fundamental study of turbulence, and optical measurement techniques.

Fellowship:
The gross salary is approximately 3000 € per month (depending on experiences) and the employer is Centrale Lille. The 24 months fellowship will ideally start around January 2024.

The position is located in a sector under the protection of scientific and technical potential (PPST), and therefore requires, in accordance with the regulations, that your arrival is authorized by the competent authority of the MESR.

Candidate:
The Post Doctoral Fellow will have expertise in experimental measurements of turbulent flows such as PIV and advanced post-processing of turbulent flow data.

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