UNIVERSITÉ CÔTE D'AZUR

Laboratoire J-A Dieudonné Mathématiques et Interactions

INPHYNI

Postdoctoral opening

Aggregation and fragmentation of flexible fibers in turbulent flow

Context: *Long, flexible fibers in turbulent flow*

The turbulent dynamics of macroscopic fibers involves a complex interplay between translation and deformation across multiple spatial and temporal scales. Its study presents a significant challenge compared to microscopic objects, whose deformation is primarily influenced by velocity gradients. Understanding the behavior of macroscopic fibers in turbulence remains largely unexplored, despite its critical implications for natural systems (planktonic colonies), industrial processes (papermaking), and environmental concerns (plastic debris in the oceans).
Previous research on fiber dynamics in turbulence has primarily focused on isolated objects, examining tumbling and spinning motions[1–3], statistical properties of deformation[4,5], and interactions with coherent structures[6–8]. Despite these efforts, fundamental questions regarding the dynamics of individual fibers remain unresolved, and there is a significant gap in our understanding of the collective behavior of fiber ensembles.
This postdoctoral position is part of a larger project aimed at understanding and modeling the processes of fiber fragmentation and aggregation. The project leverages a multidisciplinary approach, combining mathematical modeling, numerical simulations, statistical physics, and laboratory experiments.

Objectives: *Fragmentation and aggregation processes in a turbulent environment*

The objective is to develop coarse-grained mesoscopic models for long, thin, flexible fibers, such as slender bodies or articulated chains, to accurately account for break-ups, knots, fiber-fiber interactions, and entanglement. These models will be used to understand how these processes are influenced by turbulent fluctuations, aiming to provide a comprehensive statistical representation in idealized flows, both with and without boundaries. This will support the development of macroscopic descriptions necessary to address long-term global evolutions in realistic settings.

Fragmentation – Vigorous turbulent strains can cause tensile, flexural, or torsional failures of filaments[9,10]. The objective is to understand how these breakups depend on previously neglected aspects such as finite fiber length and mass, non-Markovian effects due to plasticity, and the time intermittency of the fluid flow. The aim is to explain universal distributions of fragments by addressing the following key questions:
✓ How do fibers with inertial-range sizes break up? Are these breakups related to turbulent structures?
✓ What is the effect of inertia, particularly violent inertial waves, on fragmentation processes?
✓ How can we account for plastic deformations? Is there an impact from long-term correlations of the fluid strain?
✓ Are these fragmentation processes generic? Do they result in universal daughter size distributions?

Knots, Links, and Entanglement – In turbulent flows, fibers can assemble, tie up, and form dense balls[11]. For longer fibers, flow nonlinearity or buckling can lead to the formation of knots. By considering the microscopic details of these processes, our objective is to investigate how turbulence influences, amplifies, or weakens the formation of aggregates and to develop effective models for their dynamics. Key questions include:
✓ Where and how do knots form? Can their topology be described statistically?
✓ Are there universal properties in the size, shape, and structure of aggregates?
✓ Can entangled fibers be described as porous, deformable objects with effective dynamics?

Proposed Methodology

The proposed method consists in employing simplified coarse-grained models of fibers, such as slender-body theory and bead-spring chains used in the kinetic theory of polymeric fluids. These models will be implemented in existing highly-parallel spectral codes, which are capable of accurately resolving the full complexity of turbulent flows. Simulations will be conducted in ideal geometries, including homogeneous isotropic turbulence, channel flows, and Couette flows. Medium-size simulations will utilize the HPC cluster "Azzurra" at Université Côte d'Azur, while the largest and most computationally demanding will be done on national computing centers.
The numerical simulation results will be validated through experimental collaborations with our project partners. Experiments are conducted in a turbulent von-Kármán-like flow by G. Verhille at IRPHE in Marseille and in a turbulent channel flow setup by C. Brouzet at INPHYNI in Nice. These experimental setups will provide critical data to corroborate our simulation outcomes and refine our models.

Expected Profile

This recruitment aims to enhance our team with expertise to tackle the complex numerical challenges anticipated, particularly in implementing coarse-grained models of long fibers in massively parallel simulation codes. We seek an experienced postdoctoral fellow capable of contributing to the optimization and use of parallel codes and performing statistical analysis of large-scale simulations. The candidate will also engage in analytical developments, conceive new modeling approaches, and collaborate with experimental teams at IRPHE in Marseille and INPHYNI in Nice on numerical and experimental comparisons.
Applicants should preferably hold a PhD in Physics, Mathematics, or Mechanical Engineering. Proficiency in English and significant programming experience (preferably in C or C++) are required.
We are looking for candidates who are rigorous, demonstrate independent and creative thinking.

Host Laboratories

The hired postdoctoral fellow will be jointly supervised by Jérémie Bec and Dario Vincenzi, who are affiliated with the physics department (Institut de Physique de Nice) and the mathematics department (Laboratoire J.-A. Dieudonné) of Université Côte d'Azur, respectively. Depending on the project's activities and stages, the postdoc will be hosted at one or both of these institutes, both located in Nice.
The Laboratoire J.-A. Dieudonné specializes in advanced research in pure and applied mathematics. The postdoc will join the "Numerical Modeling and Fluid Dynamics" team, interacting with experts in the numerical and theoretical modeling of turbulent transport. At the Institut de Physique de Nice, the postdoc will be part of the "Nonlinear and Out-of-Equilibrium Physics" team, which focuses on statistical physics, fundamental aspects of turbulence, turbulent transport, and large-scale direct numerical simulations of turbulent flows. In addition to interacting with members of this team, the postdoc will have opportunities to collaborate with experimentalists studying the dynamics of flexible particles in turbulent channel flows.

Duration and benefits

This postdoctoral position will be subject to a finite-term contract of 24 months with Université Côte d'Azur, starting no later than January 1, 2025. The gross salary will be approximately 3524 €/month.
Benefits include skill development opportunities (training, career and mobility counseling), 2 days of telecommuting per week, 45 days of leave per year, a sustainable mobility package (cycling, carpooling), partial coverage of public transport expenses, partial coverage of health insurance, sports activities, cultural offers, and leisure clubs, social aids and benefits, support for parenting.

To apply

Interested applicants are welcome to get in contact with Dario Vincenzi (dario.vincenzi@univ-cotedazur.fr) and Jérémie Bec (jeremie.bec@univ-cotedazur.fr). The application procedure requires to send them the following documents

1. a Curriculum Vitae;
2. a motivation letter;
3. a research statement, including a description of the experience acquired during the PhD thesis;
4. at least two recommendation letters.

Applications should be received by 10 September 2024.

Bibliographical references

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