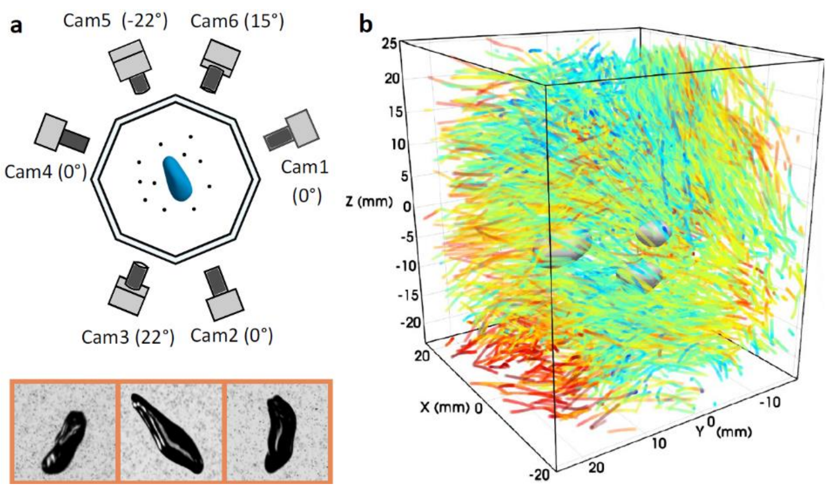
Deformation and migration in shear-driven flows

Topics: experimental; turbulent two-phase flows; deformation; break-up; data and image processing
Labs: Laboratoire des Ecoulements Géophysiques et Industriels (LEGI), Grenoble, France
Johns-Hopkins University (Fluid Transport Lab), Baltimore, USA

Context: In the production of food emulsions, droplets undergo extreme conditions, being propelled through narrow orifices with diameters around O(100) µm at velocities reaching up to O(100) m/s. This intense process generates turbulent forces that shred micron-scale fat droplets into nanometer-scale particles. This remarkable fragmentation is thought to be driven by highly localized and intense turbulence. On the contrasting end of this spectrum lie the intricate dynamics beneath breaking ocean waves. This captivating natural phenomenon involves the rupture of large gas pockets into plumes of smaller bubbles due to ambient turbulence. The resulting bubble size distributions stem from sequential breakups influenced by turbulent forces.

Project: This doctoral project will investigate bubble/droplet deformation and migration in homogeneous turbulent shear flow, where uniform shear and turbulence are present throughout the system. This approach allows for a systematic analysis of the effects of controlled mean shear on bubble breakup across different viscosity ratios. The insights gained will serve as stepping stones toward understanding fragmentation dynamics in more complex shear flows. Ultimately, the goal is to uncover the interplay between turbulence and mean shear in determining bubble/droplet breakup pathways and resulting size distributions in inhomogeneous anisotropic systems.



By leveraging the collaborative effort between two labs—one focusing on the canonical configuration in homogeneous turbulent shear flow and the other on practical applications in turbulent jets and pipe flows—this project will advance three key areas:
1) Experimental methods in turbulent multiphase flows, including diagnostic techniques for simultaneously measuring bubbles and turbulence and unique large experimental facilities (see figure)
2) New insights into how large-scale shear and small-scale turbulence interact, either collaboratively or antagonistically, to control bubble deformation
3) The generalization of this understanding to deformable particles, such as oil droplets. This will extend our framework and predictive tools to applications like homogenization in the food industry, mass transfer modeling in oceanography, and thermal hydraulics in power plants.

References: Ni, R. (2024). Deformation and breakup of bubbles and drops in turbulence. Annual Review of Fluid Mechanics, 56(1), 319-347.

Please contact Nathanaël Machicoane (nathanael.machicoane@univ-grenoble-alpes.fr) and Rui Ni (rui.ni@jhu.edu) to apply for this position or ask any questions you may have.