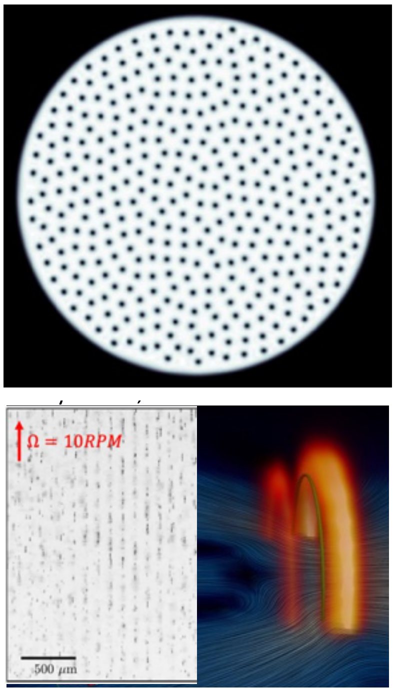
Postdoc position

Quantum vortices and inertial waves in rotating superfluid helium

Duration: 2 years, no later than September 2024
Institution: Laboratoire J.L. Lagrange. Observatoire de la Côte d'Azur. Nice, France.
Funding provided by: ANR QuantumVIW
Contact: Giorgio Krstulovic (https://www.oca.eu/fr/giorgio-krstulovic)
Deadline for application: 31/05/2024

The project:

Superfluidity is a fascinating and exotic state of matter that originates from quantum effects at very low temperatures. A *superfluid* is a liquid distinguished from a classical fluid by the absence of molecular viscosity. Consequently, an object that moves through it at low velocity does not experience any drag. Examples of superfluids are 3He and 4He, Bose-Einstein condensates (BEC) made of dilute alkaline gases, light in optical non-linear systems, and the core of neutron stars. The applications of superfluids range from cooling superconducting materials and infrared detectors to pure fundamental research in cold atoms and turbulence. The most manifest quantum effect in superfluid turbulence is the presence of quantum vortices. Such vortices are like atomic tornados, with a circulation that is quantised. In systems such as 3He and 4He and atomic BECs, quantum vortices behave as hydrodynamic vortices, reconnecting and rearranging their topology.



Top: An Abrikosov lattice of a low-temperature superfluid under rotation obtained from the Gross-Piteavskii model. **Bottom left**: Observation of the lattice in superfluid helium by the CryoLEM experiment, courtesy of M. Gibert (Néel, Grenoble). **Bottom right**: A superfluid vortex ring (green) accompanied by two normal fluid rings obtained from the fully coupled model of superfluid helium at finite temperatures FOUCAULT.

One of the most classical experiments with superfluids is a rotating bucket filled with superfluid helium. In a rotating superfluid, when rotation is smoothly increased, quantum vortices are nucleated one by one to match the global circulation of the system as closely as possible. The image shows how vortices arrange themselves in a very regular lattice. This picture is well understood at very low temperatures. At finite temperatures, superfluid helium is an immiscible mixture of a *superfluid* and a *normal fluid* described by the Navier-Stokes equations. The superfluid vortices and the normal fluid interact in a non-trivial manner, creating a very rich system. For example, superfluid vortices are accompanied by normal fluid vortex structures, as also shown in the image.

This project aims to provide numerical and theoretical support to the experiment CryoLEM at LEGI Grenoble. This unique experiment can produce and visualise in real time a stable vortex lattice in rotating superfluid helium. The successful applicant is expected to perform numerical simulations of the self-consistent model FOUCAULT. This recently developed model can accurately describe the interaction between quantum vortices and the normal fluid. More precisely, **the project aims to understand the effect of rotation and counterflow (mean relative velocity between the superfluid and the normal fluid) on the dynamics of quantum vortices and the normal fluid**. Other superfluid models might be used to complement and answer related scientific questions. This project contains an important numerical part, but analytical theories will be developed whenever possible. The successful applicant will strongly interact with all partners of the ANR QuantumVIW.

Applicant profile and required experience:

Applicants should have good theoretical understanding of fluid dynamics, turbulence and, ideally, some knowledge on superfluid vortex dynamics. Experience in high-performance computing (HPC) will be appreciated. Fluent written and oral English is essential.

Research environment:

The work will be carried out within the framework of the ANR QuantumVIW project. This project regroups experts on theory, numerical simulations and experiments of superfluid helium, classical fluids and inertial waves. The ANR QuantumVIW is composed of four partners: Institut Néel (Grenoble), FAST (Orsay), Laboratoire J.L. Lagrange (Nice) and LEGI (Grenoble). The successful applicant will join the group in Nice led by Giorgio Krstulovic (Laboratoire J.L. Lagrange). They will also take advantage of experts in classical and quantum turbulence, magnethodrodynamics, plasmas, particle transport, applied mathematics and computational fluid dynamics of the Fluid and Plasma group at Lagrange. The candidate will also benefit of the existent collaboration with Luca Galantucci on the use and development of the self-consistent model FOUCAULT.

Enquiries and Application Process

For more information about this postdoctoral position, please contact Giorgio Krstulovic (krstulovic at oca.eu)**.** You may be asked to submit the following documentation: cover letter, recommendation letters and your CV by email.

Fundings and additional information

The successful applicant will be fully funded by the ANR project QuantumVIW