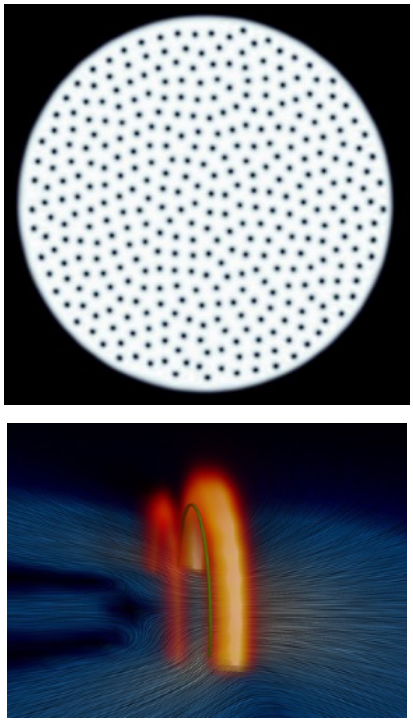
Master internship

Dynamics of superfluid helium under rotation

Duration: flexible
Institution: Laboratoire J.L. Lagrange. Observatoire de la Côte d'Azur. Nice, France.
Funding provided by: ANR GIANTE
Contact: Giorgio Krstulovic (https://www.oca.eu/fr/giorgio-krstulovic)
Deadline for application: open

The project:

Superfluidity is a fascinating and exotic state of matter that originates due to quantum effects at very low temperatures. A superfluid is a liquid distinguished from a classical fluid essentially 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 ^{3}He and ^{4}He 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** : A superfluid vortex ring (green) accompanied by two normal fluid rings obtained from a fully coupled model of superfluid helium at finite temperatures.

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 in order to match as close as possible the global circulation of the system. As shown in the image, vortices arrange themselves in a very regular lattice. This picture is well understood at very low temperatures. At finite temperatures, superfluid helium can be understood as an immiscible mixture of a superfluid and a normal fluid described by the Navier-Stokes equations. 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 vortices, as also shown in the image.

This master project aims at studying a superfluid under rotation at finite temperatures. In particular, on how superfluid vortices in the lattice interact with the surrounding normal fluid under rotation. The

problem will be addressed numerically using a recently fully coupled model of vortex filament and Navier-Stokes equation. The project will be carried on in strong collaboration with Luca Galantucci from Newcastle University.

More details on the model can be found in https://gkrstulovic.gitlab.io/project/foucault/

Applicant profile:

Applicants should have a good background in fluid mechanics and numerical methods. A good knowledge of statistical physics will be appreciated. After the master internship completion, the successful applicant is expected to have learned about finite temperature superfluids, vortex dynamics and to develop skills on numerical methods data analysis.

Research environment:

The successful applicant will join the ANR GIANTE project led by Giorgio Krstulovic, a CNRS researcher at the Fluid and Plasma Turbulence group of Laboratoire J.L. Lagrange hosted by Observatoire de la Côte d'Azur (https://www.oca.eu/en/fluid-home). The group is composed of experts in classical and quantum turbulence, magnethodrodynamics, wave turbulence, plasmas, particle transport, applied mathematics and computational fluid dynamics.

Enquiries and Application Process

To apply for this master project or further discussion, please contact Giorgio Krstulovic (krstulovic_at_oca.eu) in the first instance. You may then be asked to provide complementary documentation.

Please visit the webpage of the ANR GIANTE for other possible internships.