Master de Physique Fondamentale et Appliquée
Université de Tours
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PROPOSITION DE STAGE DE MASTER 1

Berezinskii-Kosterliz-Thouless transition of 2d superfluids : Monte-Carlo simulation of vortex/anti-vortex Coulomb gas

The Berezinskii-Kosterlitz-Thouless (BKT) transition[1], is a topological phase transition that occurs in two-dimensional systems with continuous symmetries. A hallmark of this transition is the unbinding of vortex-antivortex pairs, which drives a fundamental change in the system's behaviour. Such transitions are observed in systems like superfluid helium and thin-film superconductors, whose thermodynamic properties can be modelled by the XY model of planar spins.

This project aims to investigate the BKT transition in two-dimensional superfluids using a Monte Carlo simulation of the vortex/anti-vortex Coulomb gas (see Fig. 1). Unlike direct spin-based simulations of the XY model, this approach explicitly models vortices and their interactions, enabling a more direct examination of topological excitations and their role in the transition. The study will focus on analysing the system's behaviour at varying temperatures, computing the interaction energy of vortex pairs, exploring the vortex density, and characterizing critical phenomena associated with the transition.

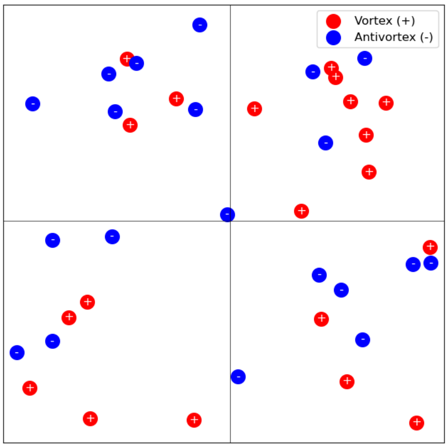

FIGURE 1 – Vortex configuration as a two-dimensional Coulomb gas.

Internship Focus

This internship is an introduction to low temperature quantum phenomena. It will explore the theoretical statistical and computational modelling of two-dimensional superfluid phase transition. Specifically, the project will involve :

- Understanding the origin of the XY-model, vortices and its mapping to Coulomb gas.
- Implementing a Monte-Carlo (MC) code to study the 2d Coulomb gas.
- Develop tools to monitor the density of free charges (vortices) and to calculate the pair correlation function of charges to identify the transition from bound to unbound states.

Candidate Expectations

- A solid understanding of statistical physics and computational techniques, and a familiarity with programming and numerical methods.
- Regular attendance and participation to the Numerical Simulation classes.
- Interest for low temperature phenomena, motivation for computational modelling.

Contact

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1. Nobel Prize in Physics 2016 : https://www.nobelprize.org/prizes/physics/2016/summary/