Contribution ID: **82** Type: **Poster**

Critical Velocity and Vortex Nucleation for Superfluid Flow Past a Finite Obstacle

Monday 2 September 2024 17:00 (2 hours)

When a superfluid flows about a cylindrical obstacle, vortex-pairs are shed by the obstacle when the critical velocity is exceeded. This phenomenon was characterised in a theoretical study using the Gross-Pitaevskii equation by Frisch et al. (1992)[1]. They investigated this behaviour for an infinite obstacle (zero density inside) and found that above the critical velocity, vortex-pairs would arise at the obstacle's lateral edges. More recently, a study by Stockdale et al. (2021)[2] looked at vortex pinning in a superfluid flow about a finite cylindrical obstacle (non-zero density inside). At some velocity, a vortex-pair nucleated inside the obstacle. The vortices moved outwards with increasing velocity and were shed by the obstacle at the critical velocity.

This study aims to characterise vortex nucleation and subsequent shedding for a finite cylindrical obstacle within a superflow in 2D. Using an analogy to Maxwell's equations of electromagnetism, we have developed an analytical model for stationary states of the system using hydrodynamics and the point vortex model. The model predicts the vortex nucleation velocity and the critical velocity.

The analytic results for single vortex-pair solutions have been compared to numerical stationary solutions of the Gross-Pitaevskii equation. We have found good agreement for larger and weaker obstacles. This is likely due to the reduced validity of the hydrodynamic approximation and point vortex model for smaller, stronger obstacles. Numerically, for large obstacles we have found solutions with two and three vortex-pairs. We will present a map of the full excitation spectrum of an obstacle with multiple vortex-pair solutions.

References

[1] T. Frisch, Y. Pomeau, S. Rica, Phys. Rev. Lett. 69(11), 1644 (1992).
[2] O. R. Stockdale, M. T. Reeves, M. J. Davis, Phys. Rev. Lett. 127(5), 255302 (2021).

Short bio (50 words) or link to website

I commended my PhD studies at the University of Queensland earlier this year. The aim of my project is to theoretically study the behaviour of the flow of a polariton condensate past an obstacle.

Relevant publications (optional)

Career stage

Student

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Presenter: QUIRK, Charlotte

Session Classification: Posters I

Track Classification: FINESS