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Superfluidity with Penetrable Obstacles

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When a conservative superfluid flows about an impenetrable cylindrical obstacle, vortex pairs will arise at the lateral edges of the obstacle and be shed into the background fluid flow when the critical velocity is exceeded. This phenomenon was characterised using the Gross-Pitaevskii equation in a theoretical study by Frisch et al. in 1992 [1]. In 2021 Stockdale et al. [2] looked at vortex pinning in a superfluid flow about a penetrable cylindrical obstacle (with non-zero superfluid density inside). They found that above a particular flow velocity a vortex pair would nucleate inside the obstacle. Using the Gross-Pitaevskii equation, we have since shown that increasing the superfluid velocity would cause the vortices in the pair to move towards opposite sides of the obstacle boundary and be shed once they reach the edges.

This study aims to numerically characterise the stationary solutions for the system which include vortex pairs for a penetrable cylindrical potential obstacle within a conservative superfluid flow in two-dimensions. We observed multiple coexisting solution pathways with varying quantities and configurations of vortex pairs. We present a map of these solution pathways as a function of superfluid flow velocity and classify the dynamical stability of each.

Finally, we will present our findings of vortex formation for a superfluid flow past a penetrable obstacle for a driven-dissipative superfluid of exciton-polaritons. Excitons-polaritons are quasiparticles which are formed by the strong coupling between an exciton (electron-hole pair) and a photon. We present an experimentally realistic protocol with which we can control the superfluid flow velocity while simultaneously observing spontaneous vortex formation. We compare the vortex solutions to those observed in the conservative superfluid system.

[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).

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